THE EFFECT OF BALCONY ON THERMAL PERFORMANCE OF HIGH RISE OFFICE BUILDING IN TROPICAL CLIMATE

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To:

My Beloved Father, Mother, Sisters and Brothers

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ABSTRACT

The design of balcony has been incorporated into the design of high-rise residential buildings, but has not been well considered in commercial high-rise buildings such as a high-rise office building except for the bioclimatic high-rise buildings. Balcony, which is referred to as an efficient wind box, functions as a thermal control element in buildings by minimizing heat gain into the interior spaces, thus reducing the amount of energy used for cooling load in buildings. This research aims at investigating the effect of balcony on the thermal performance of the interior spaces of high-rise office building. Balcony with the depth of 1m, 1.5m, 2m, and 2.5m were investigated on the 1st, 15th, 25th and 40th floor level at the north, south, west and east orientation of high-rise office building. Cap Square high-rise office building which is situated in the tropical city of Kuala Lumpur was used as a case model. A computer simulation software (Ecotect) was used for the evaluation of the indoor air temperature of the high-rise office with and without the balcony. The investigation was observed during the office hours from 9am to 6pm on the 22nd of March, 22nd of June, 22nd of September and 22nd of December. The result revealed that, on the 22nd of March and the 22nd of June, the maximum reduction of 1.83°C and 1.75°C (respectively) was recorded on the 1st floor level at the west orientation with the balcony of 2.5m, while on the 22nd of September and the 22nd of December, the maximum reduction of 0.31°C was recorded on the 40th floor level at the west orientation with the balcony of 2.5m when the indoor air temperature of the high-rise office buildings with and without the balcony were compared. This study further revealed that, the balcony with the depth of 2.5m is recommended for the 1st, 15th and 25th floor level on the west, north and east orientation, while the balcony of either 2.0m or 2.5m is recommended for the 40th floor level on the south, west and east orientation of high-rise office building.

ABSTRAK

Reka bentuk serambi telah digabungkan ke dalam reka bentuk bangunan tinggi kediaman tetapi masih belum dipertimbangkan ke atas bangunan tinggi komersial seperti bangunan tinggi pejabat kecuali pada bangunan bioiklim tinggi. Serambi, seringkali disamakan sebagai kotak angin yang cekap berfungsi sebagai elemen kawalan haba dalam bangunan dengan meminimumkan penyerapan haba ke dalam ruang dalaman, sehingga, dapat mengurangkan jumlah tenaga yang akan digunakan untuk penyejukan bahagian dalaman bangunan. Kajian ini bertujuan untuk menyiasat kesan serambi terhadap prestasi haba daripada ruang bahagian dalaman bangunan tinggi pejabat. Serambi dengan kedalaman 1m, 1.5m, 2m, 2.5m telah disiasat pada tingkat satu, tingkat 15, tingkat 25 dan tingkat 40 di bahagian utara, selatan, barat dan timur bangunan tinggi pejabat. Bangunan tinggi pejabat 'Cap Square' yang terletak di bandar tropika Kuala Lumpur telah digunakan sebagai model kes kajian. Perisian simulasi komputer (*Ecotect*) telah digunakan bagi menilai suhu udara di bahagian dalaman bangunan tinggi pejabat dengan serambi dan tanpa serambi. Siasatan telah dilakukan dan diperhatikan ketika waktu pejabat antara jam 9:00 pagi hingga 6:00 petang pada 22 Mac, 22 Jun, 22 September dan 22 Disember. Hasilnya menunjukkan bahawa pada 22 Mac dan 22 Jun, penurunan maksimum sebanyak 1.83^{o}C dan 1.75^{o}C tercatat pada tingkat satu di bahagian timur, manakala pada 22 September dan 22 Disember, penurunan maksimum sebanyak 0.31^{o}C direkod pada tingkat 40 di bahagian barat dengan serambi pada kedalaman 2.5m ketika udara dalaman bangunan tinggi pejabat dengan serambi dan tanpa serambi dibandingkan. Kajian ini mendedahkan bahawa, serambi dengan kedalaman 2.5m disyorkan bagi tingkat satu, tingkat 15 dan tingkat 25 di bahagian barat, utara dan timur, manakala serambi dengan kedalaman 2.0m atau 2.5m disyorkan bagi tingkat 40 di bahagian selatan, barat dan timur bangunan tinggi pejabat.

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LIST OF ABBREVIATION

3D	-	Three Dimensional
ASHRAE	-	American Society of heating, Refrigerating and Air Conditioning Engineers.
BIM	-	Building Information Modelling
BM	-	Building Model
CAD	-	Computer Aid Design
CFD	-	Computational Fluid Dynamic
CIE	-	International Commission on Illumination
dwg	-	Drawing
E-glazed	-	Emissivity Glazing
EPW	-	Energy Plus Weather
FMM	-	Federation of Malaysian Manufacturers.
gbXML	-	Green Building XML Scheme
GDP	-	Group Design Partner
IESNA	-	Illuminating Engineering Society of North America
ISO	-	International Organization for Standardization.
K-Ɛ	-	Kinetic energy
OFCM	-	Office of the Federal Coordinator for Meteorology
Pdf	-	Portable Document Format
PIV	-	Particle Image Velocimeter
PMV	-	Predicted Mean Vote
POMA	-	Pressurized Zonal Model with a Diffused Air
PPD	-	Percentage of Dissatisfied Index
RH	-	Relative Humidity
RNG	-	Random Number Generator
UMNO	-	United Malays National Organisation
USGS	-	United-Stats Geological Survey

UTHM	-	Universiti Tun Hussein Onn Malaysia
U-value	-	Thermal Conductance

LIST OF SYMBOLS

(A, B, a, b, α, β)	-	Coefficients which depends on the geometric.
(ø x c) a	-	Heat capacity of air.
(β)	-	Solar altitude.
(ϕ)	-	Solar azimuth.
a	-	Surface absorptive.
ach	-	Numbers of times of the whole air volume of the space
A_i	-	Respective areas of the elements
B	-	Atmospheric extinction coefficient.
C	-	Contaminant concentration
Ce	-	Contaminant concentration at the ventilating exhaust.
Cf	-	Surface drag coefficient
C_n	-	Clearness number of the atmosphere.
cos θ	-	Extra-terrestrial irradiance on an inclined surface
$\cos \theta_z$	-	Extra-terrestrial irradiance on a horizontal surface.
Cs	-	Contaminant concentration at the supply.
E	-	Air distribution effect.
E_T	-	Equation of time.

F	-	Rectangular openings.
F_{ss}	-	The angle factor between the surface and sky
g	-	Acceleration due to gravity (ms^{-2}).
h_0	-	External surface heat transfer coefficient;
I	-	Striking solar radiation.
i and j	-	Zone in the path of ij.
I_b	-	Beam irradiance on a horizontal surface on earth.
$I_{b^{\beta}y}$	-	Beam irradiance on an inclined surface on the earth.
$I_{diff,}$	-	Diffuse sky radiation.
I_o	-	Apparent extra-terrestrial irradiance.
$I_{o^{\beta}y}$	-	Extraterrestrial hourly radiation incident on an inclined
k	-	Von Karman's constant
L_{loc}	-	Longitude of the location in degree.
L_{std}	-	Standard meridian for local time zone.
LWR	-	Temperature drop due to long wave radiating to the sky.
n^{ij}	-	Flow exponent of path.
Nu	-	Nusselt number
ϕ	-	The parameters of ventilation performance (such as air temperature, air velocity and turbulence)
p	-	Air density
P_h	-	Depth of the horizontal element.
Pi and Pj	-	Total pressure

P_v	-	The depth of a vertical projection
Q	-	Heat loss.
q	-	Solar gain
Q_c	-	Conductive heat loss of a building.
Q_i	-	Heat gain.
Qn	-	The air flow entering or leaving through each opening.
Qnet	-	Net heat need.
Re	-	Reynolds' number
S_h	-	Shadow height.
		surface oriented in any direction
S_w	-	Shadow width.
t	-	Wind shear stress
T_a	-	Outdoor air temperature.
T_{in} - T_o	-	The indoor - the outdoor temperature difference.
T_{in}	-	Indoor temperature.
Tsa	-	Sol -air temperature.
T_{sol}	-	Local solar time.
T_{std}	-	Local standard time.
u (z)	-	Airspeed at height z
UA	-	Heat loss coefficient.
U_{gl}	-	Value of glazed u value.
U_i	-	Respective values of the elements.
V	-	Airflow rates (in m^3/hr)
Vol	-	Changes in an hour.

z	-	Roughness parameter
β	-	Solar altitude angle above horizontal.
γ	-	Surface azimuth angles.
δ	-	Solar declination angle.
δ	-	Solar declination angle
θ	-	Incident angle.
θ_h and θ_v	-	Angle of incidence on horizontal and angle of incidence on vertical surfaces.
ϕ	-	Latitude of the location.
Ω	-	Profile angle.
ω	-	Solar hour angle.
ς	-	Surface tilt angle.
$\Gamma_{\phi.eff}$	-	The effective diffusion coefficient

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Over the past decade, the architecture style in Malaysia had experienced a rapid transformation, which occurred as a result of rapid economic growth and industrialization in the country. The rapid growth had led to a rapid development which resulted in the transformation of the traditional and colonial buildings (which are virtually an eclectic architectural style) into a more creative and innovative architectural style which gave rise to the establishment of high-rise buildings in most of the vibrant cities in Malaysia. The erection of high-rise buildings have put Malaysia in the forefront of the developing countries as it symbolizes a fast growing economy and a sign of progress. Today, high-rise buildings in Malaysia serve the purposes of residential and commercial buildings. High-rise building is defined by Curl (2006) as a tall structure, which comprises of many floors. Emporis (2012) further defines high-rise as a building with at least a minimum of 12 floors and a maximum of 39 floors or a multi-story building within 35 to 100 meter. The Federal Emergency Management city of Chicago defined high-rise building as an existing structure, which consists of four different categories which are; high-rise buildings over 780ft (288m) above the ground, 540ft (165m) above the ground, 275ft (84m) above ground and 80ft (24m) above ground. Thus, the researcher uses the definition by the Federal Emergency Management city of Chicago because it gives a clear variation of the possible height of high-rise buildings.

As revealed by Seung Bok Leigh, Bae and Ryu (2004); Pyoung Jik Lee et al., (2007); Myung Jun Kim and Ha Geun (2007); Chan and Chow (2010), high-rise residential buildings have been incorporated with the design of balcony, an important element of the Malay traditional house that has been incorporated into the design of the residential high-rise building in the tropical climate of Malaysia, (Ismail, 2007), but has not been incorporated into the design of conventional commercial buildings (such as the high-rise office buildings) except for the bio-climatic high-rise office buildings such as Menara Boustead (1987); Menara Mesiniage (1987-1992); IBM Plaza (1984-1987) and Menara UMNO (1996-1998) which was designed by the Malaysian architect, Ken Yeang.

As revealed by Ismail, (2007), high-rise office buildings in the tropical region of Malaysia consist of two typologies, which are; the conventional and the bioclimatic high-rise office buildings. As mentioned by Joo-Hwa Bay and Boon-Lay Ong (2004), conventional high-rise office buildings are the buildings that are designed with an international style and are built in an emotive forms that have ignored all aspects of tropical context in terms of climate, environmental as well as human needs and have made a self-expression and self-reference of aesthetics as a priority in the design. As mentioned by Olgyay and Olgyay, (1963) and Ken Yeang (1991), bioclimatic high-rise buildings (office) are the built forms that are configured in relations to the meteorological climate data of the locality (tropical climate).

Climatically, the approach of architectural design high-rise office building in the tropic is to achieve a sustainable design. The term sustainable design is defined by Brundtland, (1987) as the means to meet the needs of the present without altering the ability to meet the needs of the future generations. Often sustainable design are mostly used interchangeably with green design, therefore, the United-States Green Building Council (2005) defined green design as the design and construction practices that significantly minimizes or eliminates the negative impact of buildings on the environment as well as the occupants. The sustainability concern in a tropical climate in the building industry is to design and build towards a more bioclimatic approach (Zakaria and Ismail, 2012). Bioclimatic design approach has been properly incorporated into low and medium rise buildings, but has not been well developed in high-rise buildings (such as office buildings) (Olgyay and Olgyay, 1963). Thus, in order to achieve a bioclimatic approach in high-rise office buildings, the sustainable issues of high-energy consumption must be addressed through passive strategies with the modification of the internal climate (Zakaria and Ismail, 2012).

In the tropical climate of Malaysia, the daily temperature is always high mostly during the daytime with an average temperature which ranges between 29^{o}C and 34^{o}C (Samirah and Kannan, 1997a) and a high relative humidity which ranges between 70% to 90% throughout the year (Daghigh, Sopian, and Moshtagh, 2009). Thus, high-rise buildings are exposed to most intensity solar radiation and penetrations (Sadafi et al., 2011) which results in the use of air conditioner in order to regulate the thermal condition within the indoor spaces to a satisfactory level. This strategy (air conditioner) of regulating the indoor comfort has resulted into high consumption of energy for cooling loads. Therefore, in order to derive an alternative strategy for controlling the thermal performance within the indoor spaces of high-rise office building, an element, which can maximize the effect of a thermal mass in such a way that it minimizes the indoor temperature, is needed. Therefore, a balcony, which is one of the elements of a sustainable approach (bioclimatic) in high-rise building (Ken Yeang, 1991), is introduced to high-rise office building.

Balcony is refer to as an efficient wind box which functions as a thermal control element in building by preventing heat gain into the interior spaces as well as maximizing the heat loss in a building (Ken Yeang, 1991). However, Oxford Dictionary (2000) defined a balcony as a platform enclosed by a wall with a balustrade or railing extending outside or inside the walls of a building. Mohsen and Oldham (1977); May (1979); Tzekakis (1983); Hammad and Gibbs (1983); Hothersall, Horoshenkov and Mercy (1996); Cheung, Chau and Ng (1997); Seung Bok Leigh, Bae and Ryu (2004); Pyoung Jik Lee et al. (2007); Myung Jun Kim and Ha Geun (2007); Chan and Chow (2010) have done research on how balcony can prevent traffic noise in high-rise residential building through the use of acoustic materials. Kwong Wing Chau and Siu Kei Wong (2004) and Cheung, Chau and Ng (1997) conducted research on how a balcony with a rectangular shape can add to the value of a residential apartment building. As mentioned by Seung Bok Leigh, Bae and Ryu (2004), balconies are categorized into 3 types, which are opened balcony, enclosed balcony and extended balcony. As revealed by Seung Bok Leigh, Bae and Ryu (2004), courtyard is one of the types of balcony categorized under an enclosed balcony; therefore, as mentioned by Zakaria and Ismail (2012), researches have been done with the use of rectangle shape of balcony in buildings. Elisabeth Gratia and Andre De Herde (2007), Zollner, Winter and Viskanta (2002), Till Pasquay (2004) and Hoseggen, Wachenfeldt and Hanssen (2008) research on the passive cooling strategies in office building with a double skin façade, however, based on the review; there have not been much of researches done on high-rise office building with the balcony. Therefore, as revealed by Ken Yeang (1991) that, in order for high-rise office building in hot and humid climate to reduce the effect of high solar radiation in the interior spaces, a deep recess space such as balcony must be introduced in the exterior façade of high-rise office building. As further revealed by Ken Yeang (1991), balcony in an office building functions as an emergency evacuation, a flexible zone for planting and landscaping, a space that permit for the extension of an executive space and a semi- enclosed transitional space for the users' of the building (office) to experience and enjoy the outside view of their external environment. Therefore, the research focuses on investigating the effect of a rectangular shaped opened balcony on thermal performance in the interior spaces of the high-rise office building in a tropical climate.

1.2 Problem Statement

The sustainable issue, which is always highlighted in buildings, is the high consumption of energy (Zakaria and Ismail, 2012). Recent reports have shown that commercial high-rise buildings are one of the largest consumers of energy in tropical region. As revealed by Chirarattananon and Taweekun (2003), that the energy used in office buildings in Thailand consumed about 21% of the country's energy. As revealed by Yang, Joseph and Tsang (2008), the office buildings in China consume 10 to 20 times the energy used by residential buildings.

The Energy Commission in Malaysia (2007) also revealed that commercial buildings are the second largest user of the total energy consumed in the country after industry and transportation sector (as shown in Figure 1.1).

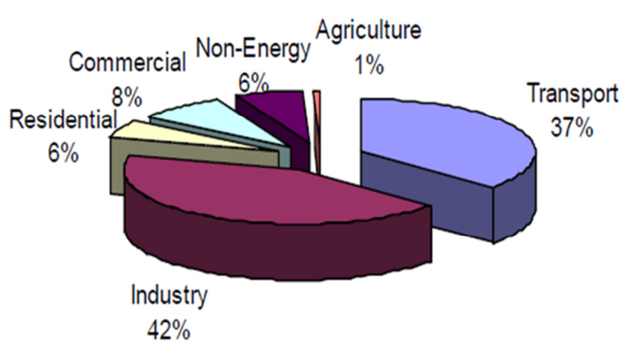

Figure 1.1: Energy used by different sectors in Malaysia

Source: Hussain, Nallagownden and Ibrahim (2011)

A study audit which was carried out by Saidur (2009) revealed that in office buildings, air conditioning consume about 57% of the main energy, followed by lighting which is 19%, lifts and pumps 18% and others 6% (as shown in Figure 1.2). The above review shows that, high-rise office building relies on the mechanical ventilation system (air conditioner) to create an artificial comfort in office buildings, thus, raising the cost of the cooling load of the users' spaces in the office buildings. As revealed by Bunn (1993), a 1^{o}C reduction in temperature is equivalent to a 10% decrease in energy consumption. Therefore, this research focuses on the techniques of reducing the indoor air temperature in high-rise office building in the tropical climate of Malaysia by investigating on the best orientation and the importance of balcony on high-rise office building.

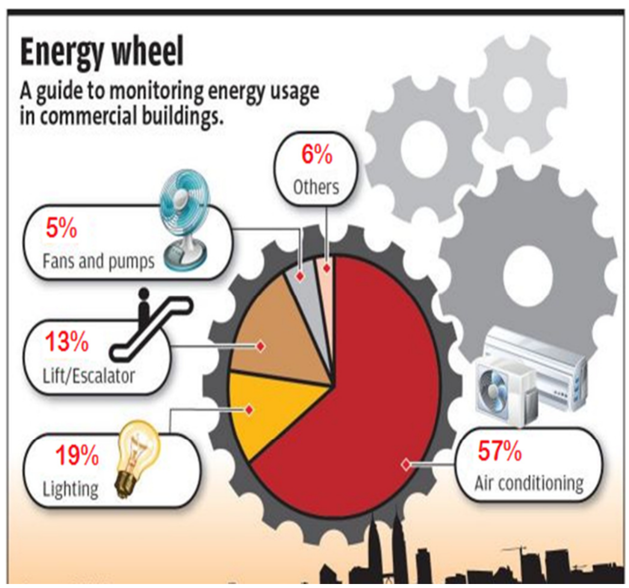

Figure 1.2: Energy usage in commercial buildings

Source: Star publication (M) Bhd (2013)

1.3 Research Objectives

The primary intention of this study is to investigate the impact of balcony on high-rise office building. In order to know how effective the impact of balcony is on high-rise office, the indoor air temperature in the interior spaces of high-rise office building with and without the balcony was investigated on. The objectives are as follows:

1. To investigate about the configurations of balconies on high-rise office buildings.
2. To investigate the depth of balcony that influences the thermal performance at the 1^{st}, 15^{th}, 25^{th} and 40^{th} floor level of the high-rise office building.
3. To investigate about the effect of balcony on the north, south, west and east orientation of the high-rise office building during the office hours (9am to 6pm).

1.4 Research Questions

The research questions give the bases of the problems to be solved. The research questions are as follows:

1. What are the configurations of balconies on high-rise office buildings?
2. What are the depths of balconies that influence the thermal performance at the 1^{st}, 15^{th}, 25^{th} and 40^{th} floor level of the high-rise office building?
3. What is the effect of balcony at the north, south, west and east orientation of the high-rise office building during the office hours (9am to 6pm)?

1.5 Scope and Limitation of Research

The scope of the research focuses on high-rise office buildings in the tropical climatic of Malaysia. The scope of the research is limited to the golden triangle area in Kuala Lumpur because a lot of high-rise buildings are located within the area. A high-rise office building called the Cap Square tower, which is situated at Jalan Munshi Abdullah in Kuala Lumpur, was selected as a case model. Cap Square Tower was selected because it fulfills the criteria of a tropical high-rise building as mentioned by Ken Yeang (1994); Kannan (1991) and Mineki Hattori (1984) in terms of the building shape (rectangular) and the position of the core location in the building, which is at the central of the high-rise office building. The building is designed with a curtain wall at the 4 sides of the façade and the case model high-rise office building is without balcony, but with exterior light shelves. In order to investigate about the effect of balcony on high-rise office building, a 3D model of the case model of the high-rise office building was modeled into two types; which are; the model with the balcony and the model without the balcony. Based on the review of previous researches as such Li et al. (2003); Hossam El Dien and Woloszyn, (2004); Tang (2010); Myung Jun Kim and Ha Geun (2007); and Pyoung Jik Lee et al. (2007), a rectangular form of balcony have been widely used in high-rise buildings, therefore, a rectangular form of balcony is selected to be modeled on the façade of the 3D model of the high-rise office building with the balcony.

As mentioned earlier (in Section 1.1), there are various definitions to high-rise building, therefore, the researcher stick with the definition as defined by The Federal Emergency Management city of Chicago, because of the classification of high-rise building into different heights which are; 80ft (24m), 275ft (84m), 540ft (165m) and 780ft (288m). Based on the design of the case model building with the floor to floor height of 4m (as specified in the building specification), the total height of the case model building is at 164m height, therefore, the height falls within the range of 540ft (165m) as defined by The Federal Emergency Management city of Chicago.

The floor level of the 3D model was classified into three parts according to the existing building specification of the case model high-rise office building, which are; the lower-rise (1-15 floor), medium-rise (16-25 floor) and high-rise (25-40 floor). Therefore, based on the theory (as illustrated in Section 2.12) and classification of the floors levels of the case model building, 1st floor, 15th floor, 25th floor and the 40th floor level were used for the investigation of the thermal performance within the office spaces. All the specifications of the case model high-rise office buildings (Cap Square tower) were taken into consideration in configuring the 3D model. During the thermal calculation, the surrounding high-rise buildings were taken into consideration as well as the wind direction and the sun path directions (the weather of Kuala Lumpur, Malaysia). The thermal analysis were observed for four days in a year (22nd of March, 22nd of June, 22nd of September, and 22nd of December) within the office hours (from 9am to 6pm). The 4 cardinal orientation, which are; east, west, north and south orientation were used for the investigation of the thermal performances within the office spaces in the high-rise office building with and without the balcony.

Due to the fact that the case model building is a sealed building (as illustrated Section 5.1.4 in the building specification, Appendix B) and depend totally on mechanical mode of ventilation, the interior spaces of the 3D model of the high-rise office building with and without the balcony were also sealed without the use of any mode of ventilation system or mechanism in order to investigate about the thermal performance (indoor air temperature) in the office spaces. Furthermore, the internal design condition, occupancy rate, operational schedule, internal gains and infiltration rate were kept constant throughout the thermal analysis calculations (all value inputted as the constant variable were obtained from the building specification in Appendix B).

The investigation of this research are totally based on the use of computer simulation software called Ecotect Analysis (2011), therefore the use of any manual device or manual experiment was not involved in the research as all the readings and the results obtained are from a computer simulation energy software.

1.6 Expected Contribution

As mentioned by Mohamed, Prasad and Tahir (2008), in the architectural perspective, the use of balcony in buildings contributes to the shape and articulation of the building, therefore, with the consideration of different design approaches, balconies could contribute to the functionality of a building as a great architectural element. Different research studies such as Mohsen and Oldham (1977); May (1979); and Li et al. (2003) had revealed how the presence of balcony have reduced noise from road traffic with the use of an acoustic material for the configuration of the balcony. Another research study by Chan and Chow (2010) revealed how the presence of balcony in a building can substantially reduce energy consumption due to the shading effect. Suzuki et al. (2001) also revealed how the presence of balcony on the façade of high-rise building (residential and commercial) can prevent the wide spread of fire in the building. Therefore, this present study investigates on how the presence of balcony on high-rise office building in the tropic affects the thermal performance (indoor air temperature) within the office spaces.

1.7 Significance of Research

The significance of the research focuses on the importance of a sustainable element (such as balcony) on high-rise office building. The benefit of dealing with sustainability is distributed in term of environmental, economic, health and safety and community benefit (United-States Green Building Council, 2005). Therefore, this research will enlighten or educate the designers, builders as well as the building occupants or users on the importance of balcony on high-rise office building. As shown in Figure 1.3, the presence of balcony on high-rise office building will improve thermal performance by preventing heat gain and maximize heat loss in the interior spaces of the office building. In terms of safety, the presence of balcony on high-rise office building façade will prevent the wide spread of fire to the upper floors of the high-rise office building in case of a fire outbreak in the interior spaces. Furthermore, this study will educate the designer, builder and the users of the building on how the use of balcony on high-rise office building can reduce energy conservation by reducing the amount of cooling load used in the high-rise office building.

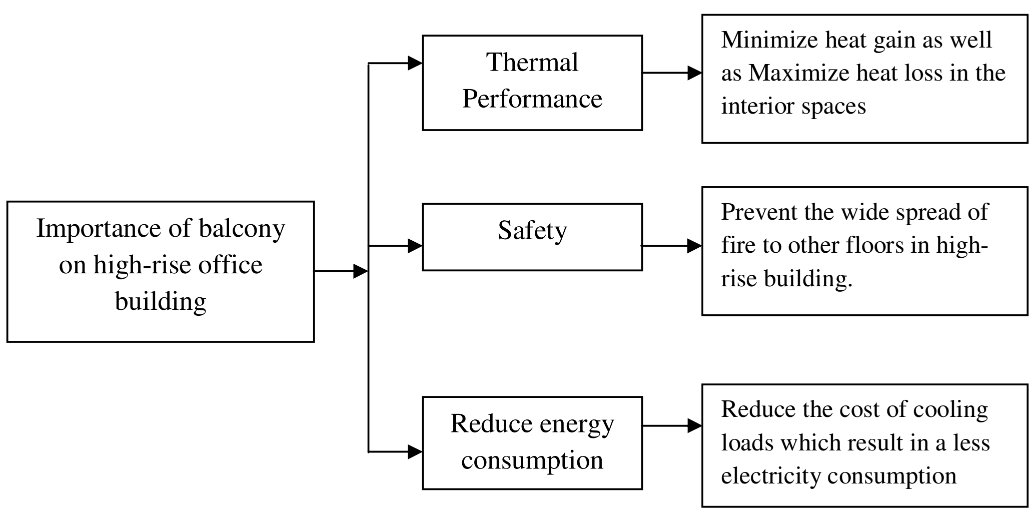

Figure 1.3: The significance of a balcony on the forms of high-rise office building

1.8 Chapter Outlines

Chapter 1: Introduction

The Chapter consists of the background of problem, problem statements, research objectives, research questions, scope and limitations of the research, expected contributions, significance of the research and Chapters outlines.

Chapter 2: Literature Review

This Chapter reviews the theory of the climate in Malaysia, and the climate of the study area, which is Kuala Lumpur, solar radiation in Malaysia, air temperature, sky condition in Malaysia and solar geometry. The Chapter further reviews the forms or shapes and features that are present in the high-rise building design and built in a tropical climate like Malaysia. This Chapter also discusses about the review of previous researches done on thermal performance of buildings in the tropical climate, therefore, the gaps of the research was properly defined based on the previous research review.

Chapter 3: Research Methodology

This Chapter discusses the methodology used for evaluating the indoor air temperature in the office space of the high-rise office building with and without a balcony. This Chapter justifies the development of basic model of the office building as well as the experimental procedures, experimental requirements, limitations and the overall stage by stage procedure of the experimental methods.

Chapter 4: Result and Analysis

This Chapter discusses the analysis derived from the simulation. The analysis gives the result of the simulation, which is based on the research questions. The analysis that will be observe during the simulation process are listed below:

a. The impact of the variation of balcony on the indoor air temperature of the high-rise office building at the north, south, west and east orientation.
b. The result of the variation of balcony at different height (floor levels) of the high-rise office building with the balcony.
c. The comparison between the indoor air temperature at the north, south, west and east orientation of the high-rise office building (with and without the balcony), at the investigated floor levels.

Chapter 5: Conclusion and Recommendation

This Chapter discusses the conclusions, which are derived from the results. In this Chapter, recommendations are given on the suitable variations of balcony and the best orientation which balcony should be located on the forms or façade of high-rise office building. Furthermore, future researches related to the area of study are recommended.

ASHRAE (1989) Handbook of Fundamentals, Chapter 14, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA.

ASHRAE (1992). Thermal Environment Conditions for Human Occupancy.American Society of Heating, Refrigerating and Air-conditioning Engineers.Standard 55. Inc. Atlanta

ASHRAE (1997). ASHRAE Handbook: HVAC Applications. American Society of Heating, Refrigerating and Air-conditioning Engineering, Inc.Atlanta

ASHRAE (2004). Thermal Environment Condition for Human Occupancy. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Standard 55. Inc. Atlanta

ASHRAE (2007). ASHRAE Handbook: HVAC Applications. American Society of Heating, Refrigerating and Air-conditioning Engineering, Inc.Atlanta

Awbi H. B. (1991). Ventilation of Buildings, E and FN Spon press. London.

Awbi H. B. (2003). Ventilation of Building. Spon press. London and New York

Awbi, H. B. (2004). Ventilation of Buildings, Second Edition, ISBN 0415270553. Taylor and Francis. London

Awbi H. B. (2007). Ventilation system design and performance.Taylor and Francis.London and New York.

Balcomb, J., and Douglas (1998). The Coming Revolution in Building design. PLEA 98: Passive and Low Energy Architecture. June 1-3. Lisbon, Portugal.

Brian Anderson. (2006). Conventions for U-Value Calculations 2006 Edition. BRE, Watford, UK.

Brundtland, G. H. (1987). World Commission on Environment and Development. Our common future. Oxford: Oxford University Press.

Bun, R. (1993). Fanger: Face to face. Building Service. The CIBSE Journal

Chan, A. L. S., and Chow, T. T. (2010). Investigation on energy performance and energy payback period of application of balcony for residential apartment in Hong Kong. Energy and Buildings, 42(12), 2400-2405.

Chand, I., Bhargava, P. K., Sharma, V. K., and Krishak, N. L. V. (1992). Studies on the effect of mean wind speed profile on rate of air flow through cross-ventilated enclosures. Architectural Science Review, 35(3), 83-88.

Cheung Tat Po, Ivan (2006). An Empirical Study to Investigate How the Provision of Balcony Influences the Property Value. Master Dissertation, Housing Management. The University of Hong Kong.

Cheung, A., Chau, K. O., and Ng, K. K. (1997). Road Traffic Noise on Balcony. The 6th Western Pacific Regional Acoustic Conference. pp. 32 -38.

Chia Sok Ling (2007). Minimizing Solar Insulation in High-rise Buildings through Self-Shaded Forms. Universiti Teknologi Malaysia. Master Thesis.

Chirarattananon, S., and Taweekun, J. (2003). A Technical Review of Energy Conservation Programs for Commercial and Government Buildings in Thailand.*Energy Conversion and Management*, *44*(5), 743-762.

Clarke, J. A. (2001). Energy Simulation in Building Design. Oxford, Butter Worth Heninemann.

Crawley, D. B., Hand, J. W., Kummert, M., & Griffith, B. T. (2008). Contrasting the capabilities of building energy performance simulation programs. Building and environment, 43(4), 661-673.

Curl, J. S. (2006). A Dictionary of Architecture and Landscape Architecture. 2nd edition, Oxford: Oxford University Press.

Daghigh, R., Sopian, K., and Moshtagh, J. (2009). Thermal comfort in naturally ventilated office under varied opening arrangements: objective and subjective approach. European Journal of Scientific Research, 26(2), 260-276.

Dalgliesh, W. A. (1975). Comparison of model full-scale wind pressures on a high-rise building. *Journal of Wind Engineering and Industrial Aerodynamics*, *1*, 55-66.

Danny, L.H.W. and Joseph, L.C. (2001). An analysis of climatic parameters and sky condition classification. Building and Environment, 36(4), 435-445.

David Little Field (2008). Metric Handbook Planning and Design Data. Oxford UK and Burlington, U.S.A. Elsevier.

Depecker, P., Menezo, C., Virgone, J., and Lepers, S. (2001). Design of buildings shape and energetic consumption. Building and Environment, 36(5), 627-635.

Djamila, H., Ming, C. C., and Kumaresan, S. (2011). Estimation of exterior vertical daylight for the humid tropic of Kota Kinabalu city in East Malaysia. Renewable Energy, 36(1), 9-15.

Donald, G. S., Chuah, S. L., and Lee (1984). Solar Radiation in Malaysia: a Study on Availability and Distribution of Solar Energy in Malaysia. Oxford University Press.

Ecotect Analysis (2011). Copyright © 2013, Autodesk, Inc. http://usa.autodesk.com/ecotectanalysis.

Ecotect Software (Accessed in 2013). www.ecotect.com.

Eldorado Weather (2013). ww.eldoradocountyweather.com. (Access 6/4/2013)

Elisabeth Gratia and Andre De Herde, (2007). Guidelines for Improving Natural Daytime Ventilation in an Office Building with a Double Skin Façade. Solar Energy. Vol. 81, Issue 4, pp 435 -448. Elsevier.

Elisabeth Gratia and Andre, D. H. (2003). Natural cooling strategies efficiency in an office building with a double-skin façade. Energy and buildings, 36(11), 1139-1152.

Emmanuel, M. R. (2004). An Urban Approach to Climate Sensitive Design; Strategies for the Tropics. London and New York; Spon press

Emporis (2012). Building Data and Construction Projects World Wide.www.emporis.com.Copyright © 2000-2014 Emporis GMBH.

Energy Commission (2007). Statistics of Electricity Supply in Malaysia. Energy Commission, Malaysia.

Energy Efficiency and Renewable Energy, (2012). World Meteorological Organization. Southeast and south west Pacific WMO Region 5: Malaysia. U.S Department of energy. Access date June 2013 http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data3.cfm/region =5_southwest_pacific_wmo_region_5/country=MYS/cname=Malaysia

Ernst and Peter Neufert (2012). Architects' Data, Blackwell Science. UK.

Fanger, P. O. (1970). Thermal Comfort Analysis and Application in Environmental Engineering.Technical University of Denmark.McGraw-Hill. Denmark

Farlex (2007). Saunders Comprehensive Veterinary Dictionary, 3Edition. Elsevier, U.S.

Federal Emergency Management Agency.High-rise building -Emergency procedure. Chicago. www.cityofchicaho.org/dam/city/depts/cfd/general/PDFs/Emergency.Preparednes s Study Guide2.pdf

Federation of Malaysian Manufacture (2013). www.fmm.org.my, Kuala Lumpur. Copyright © 2013 (Access 4/9/2013)

Feustel, H. E. (1999). COMIS—an international multizone air-flow and contaminant transport model. *Energy and Buildings*, *30*(1), 3-18.

Frank, T., Piller, Mitchell, M., and Tseng (2010). Handbook of Research in Mass Customization and Personalization. Volume 2 Application and Case. World Scientific. Singapore, USA and UK.

GDP Architects, Ar Syed Sobri Syed Ismail and Pan Choong Chong (2010). Capital Square SDN BHD, 31st floor, Menara Multi-purpose Capital Square, Jalan Munshi Abdullah, Union Investment. Kuala Lumpur.

Givoni, B. (1994). Passive and Low Energy Cooling of Buildings. Canada, United States. John Wiley and Son Inc.

Givoni, B. (1998). Climate Consideration in Building and Urban Design. New York: Van Nostrand Reinhold.

Golany, G. S. (1983). Earth Sheltered Habitat: History, Architecture and Urban Design. Van Nostrand Reinhold, New York.

Google Earth. (2013). Image Landset ©2013 Maplt, Image ©2013 Digital Globe, Data SIO, NOAA, U.S. Navy, NGA, GEBCO. Imagery Date 4/9/2013

Gould, B. J. (1972). Architectural Aerodynamics. The Architect (July) 69-71.

Hammad, R. N. S. and Gibbs, B. M. (1983). Building Façade in Hot Climate: Part 2, Applied Acoustics. Vol. 16, pp. 441 -451.

Harkness, E. L. and Mehta, M. L. (1978). Solar Radiation Control in Buildings. London: Applied Science Publishers Ltd

Hastings, R. and Wall, M. (2007). Sustainable Solar Housing Strategies and Solutions, Volume 1. Earthscan, UK and USA.

Heidt, F. D. (1994). Luftung, in Maier, K. H. (ed) Der Energieberater. Kap., 5.1.1.6, S. Verlag Deutscher Wirtschaftsdienst GmbH, Koln, Germany.

Hiroshi, Y., Yasuko, Y., Qingyuan, Z., Akashi, M., Nianping, Li., Zhenhai, Li. and Hiroyuki, M. (2006). Indoor thermal environment and energy saving for urban residential buildings in China. Energy and buildings, 38(11), 1308-1319.

Hong Lim Foo, Hamdan, M. D. and Rajeh, M. A. (2006). Towards Development of Tropical Solar Architecture: The Use of Solar Chimney as Stack Induced Ventilation Strategy. Faculty of Built Environment.UniversitiTeknologi Malaysia. Malaysia.

Hong, Tianzhen, Chou, S. K. and Bong, T. Y. (2000). Building Simulation: An Overview of Developments and Information Sources. Building and Environment, 35: 347-361

Hoseggen, R., Wachenfeldt, B. J., and Hanssen, S. O. (2008). Building Simulation as an Assisting Tool in Decision Making: Case Study: With or Without a Double Skin Façade. Energy and Buildings. Vol. 40, Issue 5, pp. 821 -827. Elsevier.

Hossam El Dien, H., and Woloszyn, P. (2004). Prediction of the sound field into high-rise building facades due to its balcony ceiling form. Applied Acoustics, 65(4), 431-440.

Hothersall, D. C., Horoshenkov, K. V. and Mercy, S. E. (1996). Numerical Modelling of the Sound Field Near a Tall Building with Balconies Near a Road. Journal of Sound and Vibration. 198(4), 507 -515.

Hussain, N., Nallagownden, P. and Ibrahim, T. (2011). Long Term Sustainable Energy Planning for Malaysia: A Modelling and Decision Aid Framework. Journal of Energy and Environment, 3(1).

Ibrahim and Zain-Ahmed (2006). Wall parameters as means to Control Discomfort Due to Solar Irradiance. Proc. Int. Symposium on Sustainable Energy and Environment. ISESEE 2006. 3-6 Dec. 2006, Kuala Lumpur

Ibrahim, N., and Zain-Ahmed, A. (2007). Daylight Availability in an Office Interior Due to Various Fenestration Options. In 2nd PALENC Conference and 28th AIVC Conference on Building Low Energy Cooling and Advanced Ventilation Technologies in the 21st Century, Crete island, Greece.

IESNA (2004). Lighting Hand Book Illuminating Engineering Society of North America, New York.

Ishwar Chand, P. K., Bhargara, N. L. V. and Krishak (1998). Effect of balconies on ventilation inducing aeromotive force on low-rise buildings. Building and Environment, 33(6), 385-396.

Ismail, A. M. (1996). Wind Driven Natural Ventilation in High-Rise Office Buildings with Special Reference to the Hot-Humid Climate of Malaysia. University of Wales College of Cardiff: Phd. Thesis.

Ismail, L. H. (2007). An evaluation of bioclimatic high rise office buildings in a tropical climate: energy consumption and users' satisfaction in selected office buildings in Malaysia (Doctoral dissertation, University of Liverpool).

ISO (1998). International Organization for Standardization, Instruments for Measuring Physical Quantities, EN ISO 7726. ISO standards for Ergonomics of Thermal Environment.

ISO (2005). International Organization for Standardization, Moderate Thermal Environments- Determination of the PMV and PPD Indices and Specification of the Conditions for Thermal Comfort ,EN ISO 7730. ISO standards for Ergonomics of Thermal Environment.

ISO., (2004). 15469: (2004) / CIE S011/E. (2003).Spatial Distribution of Daylight CIE Standard General Sky, ISO. Geneva.

Jianlei Niu (2003). Some significant environmental issues in high-rise residential building design in urban areas. Energy and buildings, 36(12), 1259-1263

Joe Clarke, Cameron Johnstone, Jaemin Kim, Georgios Kokogiannakis, Paul Strachan, Jongyeob Kim, Kyung-hun Woo, Boo-sik Kang. (2008). Study of the Energy performance of Korea Apartment Building with Alternative Balcony Configuration. Energy System Research Unit, Dept. of Mechanical Engineering, Unviersity of Strathelyde, Glassgow. UK and Samsung C and T Corporation, Republic of Korea.

John, H., Mammoser and Francine Battaglia. (2003). A computational study on the use of balconies to reduce flame spread in high-rise apartment fires. Fire safety journal, 39(4), 277-296.

Joo-Hwa Bay and Boon-Lay Ong (2004). Social and Environmental Dimensions in Tropical Sustainable Architecture: Introductory Comments. Department of Architecture, National University of Singapore.

Kannan, K. S. (1991). Thermal Characteristics of Malaysia Building Envelope. University of Malaysia, Ph.D. Thesis.

Ken Yeang (1991). Design-high-rise in tropics high-rise design for hot humid places. Building Research and Information, 19(5), 274-281.

Ken Yeang (1994). Bioclimatic Skyscrapers. Artemis London Limited, London, U.K

Ken Yeang (1996). The Skyscrapers: Bio-climatically Considered, London: Academic Editions.

Ken Yeang (2007). Eco Skyscrapers.Images Publishing, Australia.

Ken Yeang, and Hamzah, T. R. (1992). The Tropical Skyscraper, High-Rise Design for Hot Humid Places. International Conference on Tall Buildings-Reach For the Sky. Kuala Lumpur, Malaysia.

Kishor C. Mehta, William, L., Coulbourne (2010). Wind loads: Guide to the Wind Load Provisions of ASCE 7-05. Virginia,United State of America: ASCE Press.

Kondratyev, K.Y. (1969). Radiation in the Atmosphere. New York: Academic Press.

Kordjamshidi Maria (2010). Green Energy and Technology House Rating Schemes from Energy to Comfort Base. London New York: Springer Heidelbery Dordrecht.

Kotani, H., Sagara, K., Yamanaka, T., Kuise, M., Yamagiwa, M., Horikawa, S. and Ushio, T. (2006). Task Ambient Air Conditioning System with Natural Ventilation for High Rise Office Buidling (Part1: Outline of System and Thermal Environment in Working Zone). Healthy Buildings 2006, 269-274.

Kubota and Supian Ahmad (2006). Wind Environment Evaluation of Neighbourhood Area in Major Town of Malaysia. Journal of Asian Architecture and Building Engineering (JAABE).Vol.5: pp 199-206.

Kwong Wing Chau and Siu Kei Wong. (2004). Department of Real Estate and Construction. University of Hong Kong. Hong Kong.

Larasati, D. Z., Kurniawan, D. and Surjamanto (2003)."Solar Radiation Influence and Energy Using Simulations in Multi Storey Buildings in Hot Humid Area".Proceedings of International Seminar on Sustainable Environmental Architecture (SENVAR 4). October 15-16. Jakarta, Indonesia. Trysakti University. 187 -197

Le Thi Hong Na and Jin-Ho Park (2009).“Emphasis on Passive Design for Tropical High-rise Housing in Vietnam”. Proceeding of the International Association of Societies of Design Research, Seoul, Korea, pp. 218.

Li, D. H. W., Tang, H. L., Lee, E. W. M and Muneer, T. (2010). Classification of CIE standard skies using probabilistic neural networks. International Journal of Climatology, 30(2), 305-315.

Li, K. M., Lui, W. K., Lau, K. K., and Chan, K. S. (2003). A Simple Formula for Evaluating the Acoustic Effect of Balconies in Protecting Dwelling Against Road Traffic Noise. Applied Acoustic. Vol. 64, pp. 633 -653.

Li, Y., and Delsante, A. (2001). Natural ventilation induced by combined wind and thermal forces. Building and Environment, 36(1), 59-71.

Limb, M. J. (1994). Current ventilation and air conditioning systems and strategies. TN 42, Air infiltration and ventilation centre international network for information on ventilation. Brussels, Belgium. (www.aivc.org)

Lin, Y. (1999). POMA: a zonal model for airflow and temperature distribution analysis (Doctoral dissertation, Concordia University).

Little Field, D. (2005). An Architect's Guide to Running A Practice. Great Britian. Architectural Press.

Little, R. J. A. (1982). Models for Non-Response in Sample Survey. Journal of the American Statistical Association, 77, 327-350.

Lokman Hakim Ismail, Magda Sibley and Izudinshah Abdul Wahab (2011). Bioclimatic technology in high rise office building design: a comparison study for indoor environmental condition. Journal of Science and Technology, 3(2).

Malaysia Meteorological Department (2013). www.met.gov.my. Selangor. Copyright © 2013

Malaysia Uniform Building By Law (1984). Law of Malaysia Act 133 Uniform Building By-Laws (Revised).

Martin, J. H., and Jessell, T. M. (1991). Modality Coding in the Somatic Sensory System.In; Principles of Neural Science, 3 Edition. New York: Elsevier.

May, D. N. (1979). Freeway noise and high-rise balconies. The Journal of the Acoustical Society of America, 65(3), 699-704.

Mazumdar, S., and Chen, Q. (2009). A one-dimensional analytical model for airborne contaminant transport in airliner cabins. Indoor air, 19(1), 3-13.

Mineki Hattori (1984). Computer Aided Architectural Design in Japan of the Nineteen-Eighties: Design Studies, Volume 5, Issue 1, Page 3-4, Elsevier.

Mingzhi Feng and Baiyang Jin (2013). The Energy-Saving Research of Southward Balcony in Heating Area. Applied Mechanics and Materials, 291, 1072-1076.

Miyazaki, T., Akisawa, A., and Kashiwagi, T. (2005). Energy savings of office buildings by the use of semi-transparent solar cells for windows. Renewable Energy, 30(3), 281-304.

Mohamed, M. F., Prasad, D., and Tahir, M. M. (2008). A study on balcony and its potential as an element of ventilation control in naturally ventilated apartment in hot and humid climate. In International Conference on Construction and Building Technology (ICCBT) (pp. 173-180).

Mohammed, S. B. and Ahmad Sanusi Hassan (2012). The study of air temperature when the sun path direction to ka'abah: with a case study of Al-Malik Khalid Mosque, Malaysia. International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies, 3(2), 185-202.

Mohd Azuan, Z.,and Lokman, H. I. (2010). Natural ventilation approached in circular courtyard building in hot humid climate.

Mohsen, E. A., and Oldham, D. J. (1977). Traffic Noise Reduction Due to the Screening Effect of Balconies on a Building on a Building Façade. Applied Acoustics. Vol. 10, pp. 243-257.

Moore, B. (2009). Australian Concise Oxford Dictionary, Australia, Oxford University Press.

Muhammad Iqbal (1983). Introduction to Solar Radiation. Academic Press, New York.

Munn, R. E. (1970). Airflow in Urban Area. In 15-39. Urban Climates, Technical Note No. 108. World Meteorological Organization: Geneva, Switzerland.

Myung Jun Kim, and Ha Geun (2007). Field measurements of façade sound insulation in residential buildings with balcony windows. Building and environment, 42(2), 1026-1035.

Neufert (2012). Architects' Data. (4th ed.) West Sussex: Blackwell.

Nooriati Taib, Aldrin Abdullah and Sharifah Fairuz, S. F. (2010). An assessment of thermal comfort and users' perceptions of landscape gardens in a high-rise office building. Journal of sustainable development, 3(4), p153.

OFCM (2005). Federal Meteorological Handbook no.1, Surface Weather Observations and Reports Office of the Federal Coordinator for Meteorological Services and Supporting Research. Washington, U.S. Government Printing Office.

Olgyay, V., and Olgyay, A. (1963). Design with Climate: Bioclimatic approach to architectural regionalism, Princeton Press Princeton, New Jersey.

Ossen, D. R. (2005). Optimum Overhang Geometry for High-Rise Office Building Energy Saving in Tropical Climate. UniversitiTeknologi Malaysia: Ph.D. Thesis.

Oxford Advanced Learner's Dictionary (2000). Oxford University Press, Oxford

Pablo La Roche and Murray Milne (2003). Effects of window size and thermal mass on building comfort using an intelligent ventilation controller. Solar Energy, 77(4), 421-434.

Padmanabhamurty, B. (2009). Meteorological Considerations in Environmental Protection of Large Building Construction Projects. Indian Journal of Air Pollution Control. Vol. IX. No. 1.

Pasquay, T. (2004). Natural ventilation in high-rise buildings with double facades, saving or waste of energy. Energy and Buildings, 36(4), 381-389.

Pyoung Jik Lee, Kim, Y. H., Jeon, J. Y., and Song, K. D. (2007). Effects of apartment building facade and balcony design on the reduction of exterior noise. Building and environment, 42(10), 3517-3528.

Qingyan Chen (2009). Ventilation performance prediction for buildings: A method overview and recent applications. *Building and Environment*, *44*(4), 848-858.

Qingyan Chen., Lee, K., Mazumdar, S., Poussou, S., Wang, L., Wang, M., and Zhang, Z. (2010). Ventilation performance prediction for buildings: model assessment. *Building and Environment*, *45*(2), 295-303.

Robert Hastings, S. and Maria Well (2007). Sustainable Solar Housing Exemplary Building and Technologies. London ,Sterling , VA: Earthscan.

Robertson, A. S., Burge, P. S., Hedge, A., Sims, J., Gill, F. S., Finnegan, M., and Dalton, G. (1985). Comparison of health problems related to work and environmental measurements in two office buildings with different ventilation systems. British medical journal (Clinical research ed.), 291(6492), 373.

Sadafi, N., Salleh, E., Haw, L. C., & Jaafar, Z. (2011). Evaluating thermal effects of internal courtyard in a tropical terrace house by computational simulation. Energy and Buildings, 43(4), 887-893.

Saidur, R. (2009). Energy consumption, energy savings, and emission analysis in Malaysian office buildings.Energy Policy, 37(10), 4104-4113.

Samirah A. R. and Kannan K. S. (1997a). A study of thermal comfort in naturally ventilated classrooms: Towards new indoor temperature standards. In Proceeding of the Asia Pacific Conference on the Built Environment, Nov (pp. 3-6).

Samirah, A. R., and Kannan, K. S. (1997b). Air flow and thermal simulation studies of wind ventilated classrooms in Malaysia. Special Issue World Renewable Energy Congress, Energy Efficiency and the Environment. Renewable Energy, 8(1-4), 264-266.

Schlichting, H., Gersten, K., and Gersten, K. (2000). Boundary-layer theory. 8th Revised and Enlarged edition. New York. Springer.

Seung Bok Leigh, Bae, J. I., and Ryu, Y. H. (2004). A study on cooling energy savings potential in high-rise residential complex using cross ventilated double skin façade. Journal of Asian Architecture and Building Engineering, 3(2), 275-282.

Shahriar, A. N. M., and Mohit, M. A. (2006). Frequency distribution of CIE standard general skies for Subang, Malaysia. Architectural Science Review, 49(4), 363-366.

Singh, M. K., Mahapatra, S., &Atreya, S. K. (2010). Thermal performance study and evaluation of comfort temperatures in vernacular buildings of North-East India.*Building and environment*, *45*(2), 320-329.

Sonia A. P. (2005). Development of an integrated building design information interface (Doctoral dissertation, Texas A and M University).

Sowell, E. F., and Hittle, D. C. (1995). Evolution of building energy simulation methodology. ASHRAE Transactions-American Society of Heating Refrigerating Air conditioning Engin, 101(1), 850-855.

Star Publications (M) Bhd. (2013). Business to Set Thermostats Higher to Cope with Electricity Tariff Hike. Published: Sunday December 29, 2013 MYT 12:00 am.

Sustainable Energy and Environment Forum and the Green Mechanics (2013). www.thegreenmechanics.com (access 4/8/2014).

Suzuki, T., Sekizawa, A., Yamada, T., Yanai, E., Satoh, H., Kurioka H., Kimura, Y., (2001). An Experimental Study of Ejected Flames of a High-Rise Buildings. Technical Report, National Research Institute of Fire and Disaster, (p.363 -373). Japan.

Szokolay, S. V. (2007). Solar Geometry. PLEA Note No.1, Dept. Of Architecture, Australia: University of Queensland

Takashi I., Montegut, C. D. B., Luo, J. J., Behera, S. K., Masson, S., and Yamagata, T. (2008). The role of the western Arabian Sea upwelling in Indian monsoon rainfall variability. Journal of Climate, 21(21), 5603-5623.

Tang, S. K. (2010). Scale model study of balcony insertion losses on a building façade with non-parallel line sources. Applied Acoustics, 71(10), 947-954.

Till Pasquay (2004). Natural ventilation in high-rise buildings with double facades, saving or waste of energy. Energy and Buildings, 36(4), 381-389.

Tzekakis, E. G. (1983). On the noise reducing properties of balconies. Acustica, 52(2), 117-121.

United-States Green Building Council. (2005). An Introduction to the US Green Building Council and the LEED Green Building Rating System. Power Point presentation on the USGBC website. www.usgbc.org/Resources/research.asp.

United-States Geological Survey (USGS) (2013). www.usgs.gov (access 28/3/2013)

Upendra. R and Richard, H. (2012). Barriers to and opportunities for advanced passive cooling in sub-tropical climates. Architectural Science Review, 55(1), 49-60.

Wong, L. T., and Chow, W. K. (2001). Solar radiation model. *Applied Energy*, *69*(3), 191-224.

Wong, P. C., Prasad, D. and Behnia, M. (2006). A new type of double-skin façade configuration for the hot and humid climate. Energy and Buildings, 40(10), 1941-1945.

Yang, L., Joseph, C. L., and Tsang, C. L. (2008). Energy performance of building envelopes in different climate zones in China, Applied Energy, 85, 800-817.

Yik, F. W. H., and Wan, K. S. Y. (2005). An evaluation of the appropriateness of using overall thermal transfer value (OTTV) to regulate envelope energy performance of air-conditioned buildings. Energy, 30(1), 41-71.

Zain-Ahmed (2000). Daylighting and shading for thermal comfort in Malaysian buildings (Doctoral dissertation, University of Hertfordshire).

Zain-Ahmed, A., Sopian, K., Abidin, Z. Z. and Othman, M. Y. H. (2002). The availability of daylight from tropical skies a case study of Malaysia. Renewable Energy, 25, 21-30.

Zakaria, M. A., and Ismail, L. H. (2012). Natural Ventilation Approached on Circular Courtyard Building in Hot Humid Climate. The International Conference on Civil and Environment Engineering Sustainability, Johor Bahru, Malaysia.

Zhang, Z., Zhang, W., Zhai, Z. J., and Chen, Q. Y. (2007). Evaluation of various turbulence models in predicting airflow and turbulence in enclosed environments by CFD: Part 2—Comparison with experimental data from literature. HVAC Research, 13(6), 871-886.

Zollner, A., Winter, E. R. F., and Viskanta, R. (2002). Experimental Studies of Combined Heat Transfer in Turbulent Mixed Convection Fluid Flows in Double Skin Façades. International Journal of Heat and Mass Transfer. Vol. 45, Issue 22, pp 4401 -4408. Elsevier.