EARTH-TO-AIR HEAT EXCHANGER SYSTEM: A STUDY ON THE ROLE OF GROUND COVER AND SYSTEM VALIDATION IN MALAYSIAN CLIMATE

BY

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A dissertation submitted in fulfilment of the requirement for the degree of Master of Science (Building Services Engineering)

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ABSTRACT

This thesis is an investigation into the performance of Earth-to-Air Heat Exchanger (EAHE) in Malaysian climate. The passive cooling technology, where the ground is used as a heat sink to produce cooler air, is an emerging of area of interest in Malaysia. The aim of this thesis is to find the best ground cover in improving the EAHE proficiency through thermal model using computer simulation. The pipe, which was used in the thermal model, has same parameters of the real pipe which is 3 inches diameter, 50 meters in length, made of PVC, has the velocity of flow air was 1 m/s and buried in a 4-meters depth. The performance of the EAHE was simulated using loam, clay, silty clay, sandy clay loam as back fill material. It was found that sandy soil is the best cover material.

خلاصة البحث

هذا البحث يقدم دراسة عن أداء نظام المبادل الحراري بين الأرض والهواء في مناخ ماليزيا، تقنية التبريد السلبي، حيث يتم استخدام الأرض كمغطس حراري لإنتاج الهواء البارد ويعتبر هذا المجال الناشئ محط اهتمام في ماليزيا. الغاية من هذا البحث هو إيجاد الغلاف الأرضي الأفضل لتحسين أداء نظام المبادل الحراري بين الأرض والهواء من خلال نموذج حراري مستخدماً النمذجة الحاسوبية. الأنبوب المعتمد في النموذج الحراري له نفس أبعاد الحالة الحقيقية وهي قطر 3 أنش ومادة الأنبوب PVC، وسرعة جريان الهواء 1 متر/الثانية، الأنبوب مدفون على عمق 4 متر وبطول 50 متر. أداء النظام المبادل جُرّب باستخدام تربة طميّة، صلصال، رمل، طين غريني، ومزيج من الطمي الصلصال الرملي وذلك كمادة ملأ. وُجد أن الرمل هو الغلاف الأرضي الأفضل.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion; it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Building Services Engineering.

....
Md. Najib Ibrahim
Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Building Services Engineering.

....
Aliyah Nur Zafirah Sanusi
Examiner

This dissertation was submitted to the Department of Architecture and is accepted as a partial fulfilment of the requirements for the degree of Master of Science in Building Services Engineering.

....
Nurul Syala Abdul Latip
Head, Department of Architecture

This dissertation was submitted to the Kulliyyah of Architecture and Environmental Design and is accepted as a partial fulfilment of the requirements for the degree of Master of Science in Building Services Engineering.

....
Khairuddin Abdul Rashid
Dean, Kulliyyah of Architecture and Environmental Design

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Haitham Alkhalaf

Signature …………………………………… Date ……………………..

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

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Affirmed by Haitham Alkhalaf.

……………………………. ………………..

Signature Date

To my Parents and Brothers

To My Beloved Wife

To my Brother Martyr Manaf Alkhalaf

To my Lovely Country Syria

TO WHOLE ISLAMIC UMMAH

ACKNOWLEDGEMENTS

First and the most, I would like to express sincere gratitude to Allah, the Almighty, for giving me the strength and the sustenance while undertaking this study.

I wish to thank International Islamic University Malaysia for offering me to doing Master in Building Services Engineering.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Saving energy is one of the most important global challenges nowadays. In the meantime, environmental concern drives this trend much further. In order to reduce greenhouse gas (GHG) emissions, as a main reason of global warming and sources of pollution. Kyoto protocol set specific targets for reduction of CO_2 emissions and encouraged two important initiatives; first, efforts on producing electricity with higher efficiency; second, on using electricity with higher efficiency and more efficient use of energy (not only reduces the consumption of electricity, but also lowers the consumption of primary energy sources).

Buildings, whether residential or commercial, mainly use energy to attain comfort for their residents. Although comfort includes visual and ergonomic, the main concern is about thermal. Air conditioning used to maintain comfort nowadays but utilities high energy. In order to reduce energy utilization of buildings, several passive techniques are introduced in attaining thermal comfort.

This study looked into one of passive cooling technology which uses the earth as a heat sink. This technology will be examined in tropical weather and to assess its implementation in both residential and commercial buildings. The usage of Erath Air Heat Exchanger (EAHE) system can be applied into conditioning system through three primary methods: direct, indirect, and isolated method. In the direct system, the building envelope is in contact with the earth surface, and the thermal conduction through building's elements and earth manages the interior temperature in Building. In the indirect system, the thermal comfort is achieved by using the conditioned air. This air is supplied through passing the air underground as in (EAHE). The isolated system uses the earth temperature to improve the efficiency of the heat pump through adjusting temperatures in the condensing coil. Geothermal heat pump is an example of an isolated system.

EAHE system takes advantage of the high thermal inertia of the soil where at sufficient depth the ground temperature is lower than the outside temperature in summer. The fresh air is drawn inside EAHE system to cool it before carry it out inside the building. EAHE system can supply conditioned fresh air to air-conditioning units which could reduce value percentage of electricity consumption in the building.

1.2 PROBLEM STATEMENT

EAHE system recently has got a broad interest in Malaysia, especially after the creation of a system of sustainability. Several local researches were carried out to investigate the implementation of this system in Malaysian climate. The first research was conducted at Universiti Teknologi Malaysia Skudai Campus, in Johor Bahru City to study the feasibility of earth cooling (Md. N. Ibrahim, 1988). The data was limited applied since the study was conducted in 1986 near one of its buildings, the microclimate data of the campus differs significantly from Johor Bahru City, Malaysia. In the morning of rainy season, a temperature as low as 24^{o}C were recorded. At that time, it was found that earth cooling was not viable since the cooling potential was not significant because ambient temperature was relatively low. About 20 years later, CoolTek house was built in Melaka, Malaysia. One of the low energy systems implemented in experimental house was earth cooling. The earth cooling system consists of a sub-soil chamber and a sub-soil duct. The sub-soil chamber was constructed from 50 mm thick, 1000 mm diameter concrete culvert, containing five concrete filled ceramic pipes standing on a concrete plinth of 300 mm depth with heavy concrete, and surface insulated lid. It was connected with 10 meters sub-soil duct with an air intake opening. It was generally concluded that the potential for earth cooled ventilation was relatively small.

Later a field investigation of earth pipe cooling technology was conducted in International Islamic University Malaysia (IIUM), Gombak Campus, and Kuala Lumpur- (A. Sanusi, L. Shao and Md. N. Ibrahim, 2013). It was found at 1 m underground, the result is most significant, where the soil temperature is 6^{o}C and 9^{o}C lower than the maximum ambient temperature during wet-hot and dry seasons, respectively. The latest study using computer simulation investigates influence of diameter, air velocity, and pipe length on earth pipe cooling (Md. N. Ibrahim, A. Nur Z. Sanusi, M. Ali, S. H. Aziz, 2013). This thesis will address the research gap to study the effect of various ground covers on the performance of earth pipe cooling.

1.3 RESEARCH QUESTION

This study aims to answer the following research question:

Which ground cover will give better cooling potential in Malaysian climate?

1.4 AIMS & OBJECTIVES

The goal of the study is to understand the cooling potential of various ground types surrounding the buried pipe in the earth-to-air heat exchanger (EAHE) system in the local climate of IIUM Gombak Campus, Malaysia.

The Objectives of the research are:

i. To identify relevant data from various sources that can be used as input into EAHE simulation.

ii. To find simulation software that can be used for the computer simulation.

iii. To build EAHE model for Gombak Campus in the simulation package.

iv. To find the best ground cover for optimum cooling.

1.5 SIGNIFICANCE OF THE STUDY & CONTRIBUTION

Cooltek is an example of a house incorporates EAHE in Malaysian climate. In the design of this house the selection of alternatives earth cover was not considered probably because the information was not available. This research should be able to provide such information for similar Green house in the future.

1.6 THESIS STRUCTURE

The thesis is structured as follows:

Chapter 1 identifies the framework of the study, the research aims and goals, and the hypothesis. Chapter 2 presents literature review which will outline the previous research and identify the variables, methodologies and model criteria which used in data analysis. Chapter 3 a review on methodology will describe the procedure for setting and running simulation and explain the source of simulation parameters.

Chapter 4 analyzes output results and validates our system by comparing our results with the results of different software for the same case study.

Chapter 5 for the discussion and recommendations of the future studies as shown in Figure 1.1.

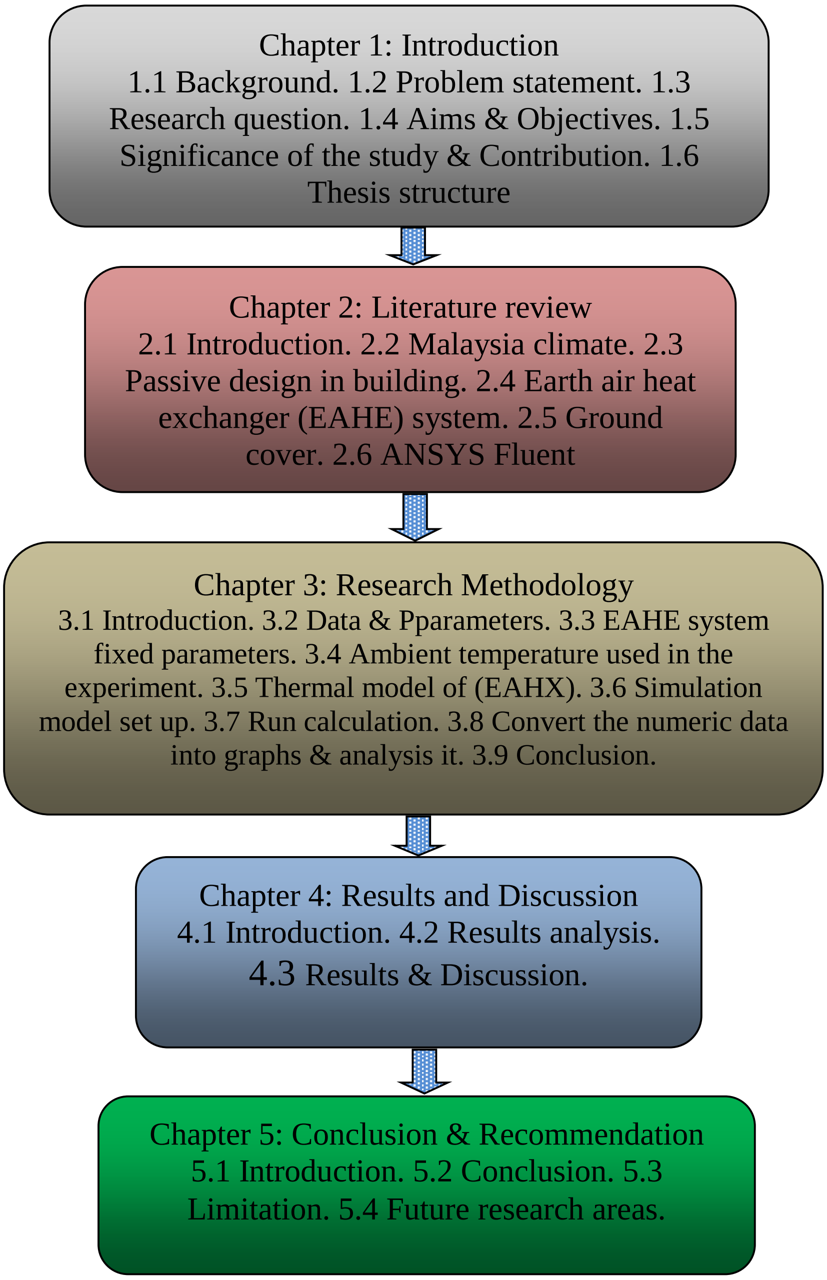

Figure 1.1 Thesis structure.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is intended to provide an understanding of EAHE technology used in our simulation. Before the simulation is conducted, it is first necessary to understand it's the underlying background information of simulation. The climate of Malaysia, in which EAHE will be tested through simulation, is explained in the next section. In the following sections the EAHE technology is reviewed including its performance parameters. Ground cover as the key EAHE parameter of this study will be discussed separately. The last section explains the computer software used for the simulation.

2.2 MALAYSIA CLIMATE

2.2.1 Location of Malaysia and Climate

The location of Malaysia on the globe determines its climate and weather distribution throughout the year. Malaysia extends from latitude of 1^{o} N to 7^{o}N and from longitude of 100^{o}E to 120^{o}E as shown in Figure 1.2. Being located close to the equator, and within the tropical region, it has a warm and humid climate, with high air temperature and high humidity level throughout the year. The only seasonal differences in Malaysia are caused by the southwest monsoon, northeast monsoon and the interval period between two monsoons. Southwest monsoon season occurs from the month of May until September. During the southwest monsoon period, the wind is usually at the maximum of 7.7m/s and blows in South-Western direction. On the other hand, the northeast monsoon season occurs from November until March. During this period, the wind is slightly stronger than in the southwest monsoon season but blows in North-Eastern direction. The North-Eastern wind can reach up to a maximum of 10.3m/s.

Malaysia climate is normally considered in terms of five environmental factors:

Dry bulb temperature (°C), Relative humidity (%), Amount of rainfall (mm), Wind speed (m/s), Direction (°C) and solar radiation (MJ/m^2) These climate parameters usually influence architects to design buildings that were responsive to the local climate. However, when the shelter does not provide adequate comfort, various cooling methods might be applied into the building interior to satisfy the occupants' thermal comfort. (http://www.worldweather.org/020/c00082.htm).

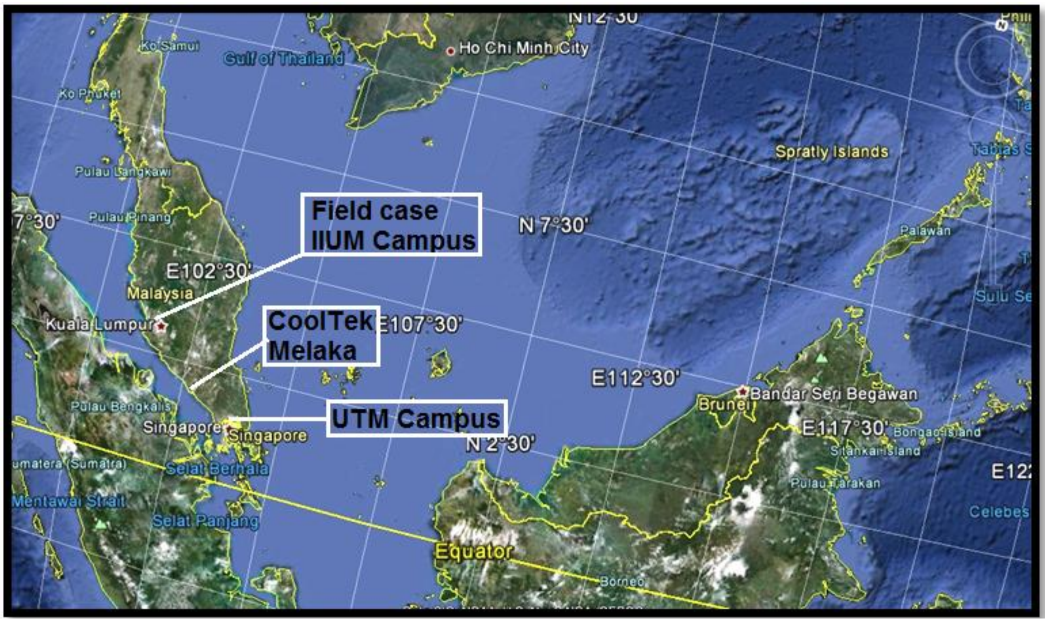

Figure 2.1 Location of Ground cooling studies in Malaysia and Malaysia's latitude and longitude.

2.2.2 Malaysia Temperature and Solar

The illustrated records of Kuala Lumpur air temperature have shown that the maximum dry bulb temperature can reach up to 36.4°C (March 2005). Figure 2.2 shows the summary of data collected from 2002 to 2008 by the Meteorology Department at Subang Jaya Weather Station.

Throughout the year 2002 and 2008, the highest absolute and mean daily maximum dry bulb temperature occurred in March, April and May (Figures 2.2 and 2.3). This period is at the end of northeast monsoon season and the beginning of southwest Monsoon season.

The lowest absolute daily minimum dry bulb temperature recorded during six years, was occurred in July, August and September as shown in Figure 2.2.

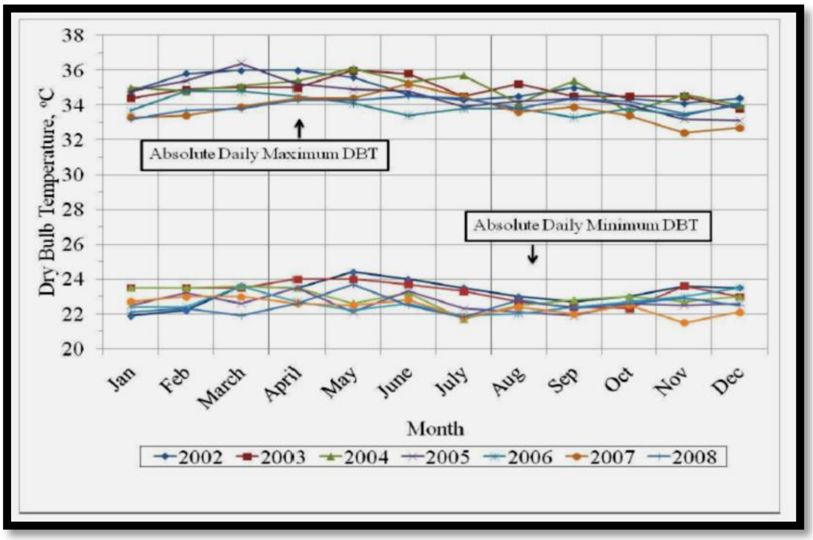

Figure 2.2 Absolute daily maximum and minimum Dry Bulb Temperature from 2002 to 2008. (A. Sanusi, 2012).

However, the lowest average daily minimum dry bulb temperature was occurred in November, which is the northeast monsoon season (Figure 2.3).

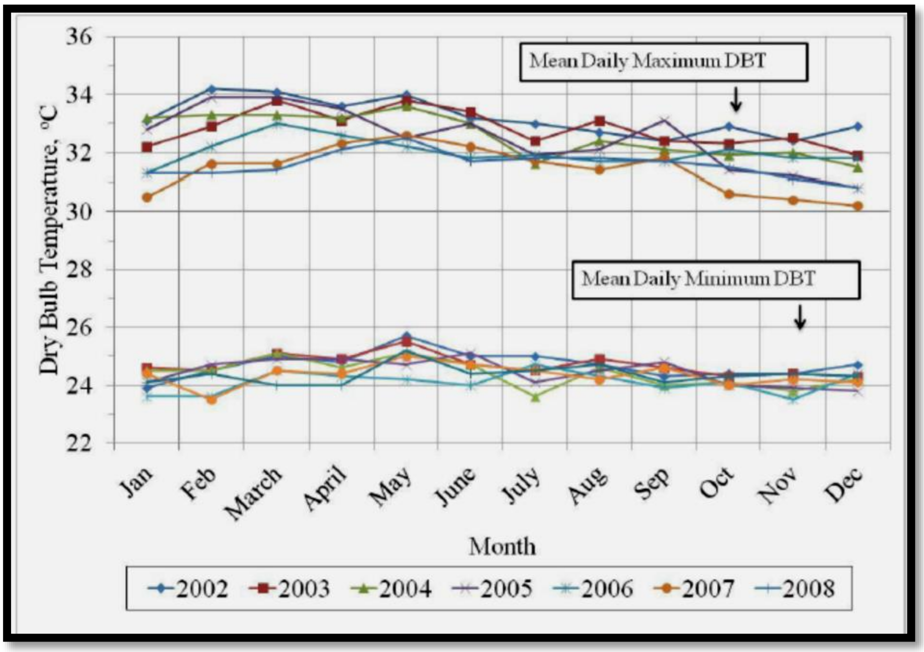

Figure 2.3 Mean daily maximum and minimum Dry Bulb Temperature from 2002 to 2008. (A. Sanusi, 2012).

In this research, it is so important to have a sufficient data about the underground conditions such as, seasonal temperature in shallow depth and the certain depth where the temperature becomes constant in addition to type of ground cover.

In this paper the constant temperature of underground will be the factor of underground properties beside to ground cover type. Figure 2.4 shows the underground temperature in different depth during October and November. The amplitudes of soil temperatures within the two months decrease with increasing depth of soil. However, soil temperature at 3m depth underground is fairly stable with amplitude similar to 5m depth soil.

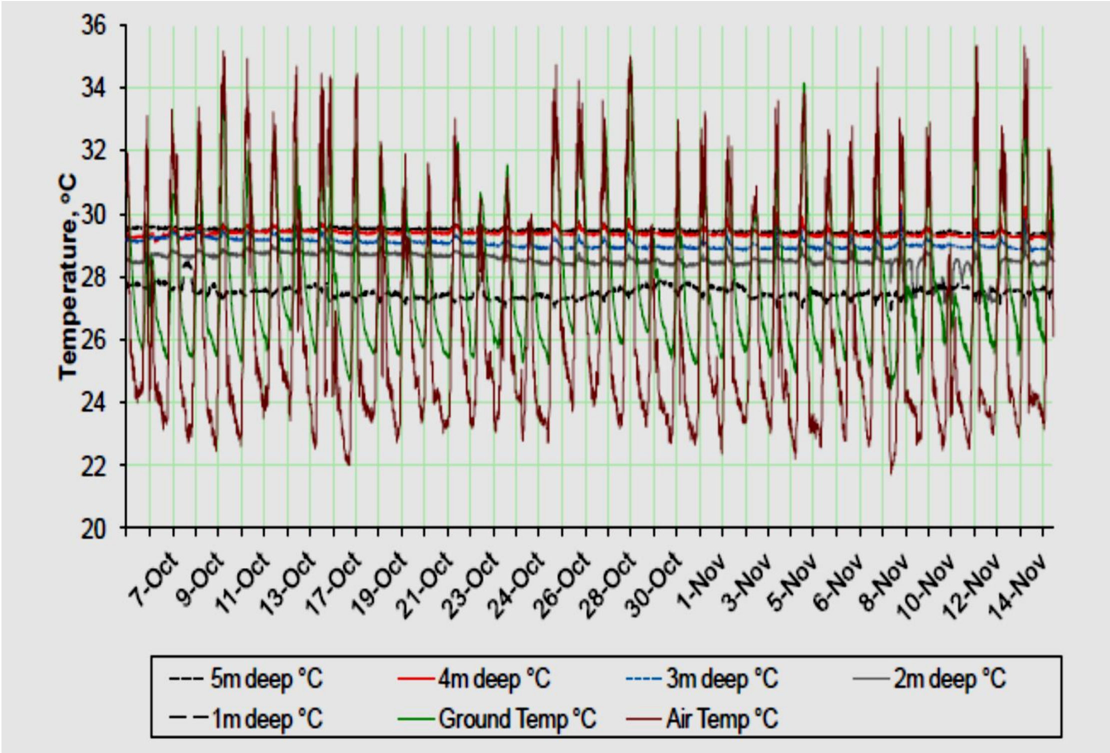

Figure 2.4 Trend of ambient air temperature and soil temperature measured (at different depths) on field site in Gombak, Malaysia from 5 October to 14 November (A. Sanusi, 2012)

Malaysia has a uniform sunrise and sunset time throughout the year. Usually the sun rises after 07:00 o'clock and sets around 19:00 o'clock. The daily average over daylight hours of solar radiation ranges from 321W/m^2 to 394W/m^2 .As sun rises, the solar radiation increases until the maximum, which occurred mostly at 12:00 pm. The solar radiation then gradually decreases until the sun sets as shown in Figure 2.5.