THE EFFECT OF COOLED SOIL IN EARTH-TO-AIR-HEAT EXCHANGER (EAHE) PERFORMANCE FOR HOT HUMID CLIMATE (OF MALAYSIA)

BY

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ABSTRACT

This research is intended to investigate the effects of cooled soil on the performance of Earth- to- Air Heat Exchanger (EAHE) in buildings in Malaysia, which experiences hot and humid climate throughout the year. EAHE has been applied in many countries for building cooling, mostly in temperate or hot and arid climate where the diurnal temperature is large. However, minimal resources were found on the study of EAHE application to buildings in Malaysia. A field experiment on EAHE application in Malaysia was carried out in 2012 (Sanusi, 2012). A parametric study was done as part of the research and it concluded that among of many parameters in EAHE design, the soil temperature which surrounds the pipe was the most influential factor. Therefore, this research compares EAHE system buried underground under three soils surface conditions; bare soil with short grasses, shaded with recycle timber pallets and insulated using recycled tyre. This research method consists of data collection from soil measured in a test site for a month then simulated into Energy Plus software to obtain temperature difference, between inlet temperature (ambient) and outlet temperature (to building). This research found that soil insulated using recycled tyre at 1.0 m depth recorded the lowest amplitude temperature outlet among all with 26.708^{o}C at minimum, while 27.172^{o}C. Findings showed noticeable differences between inlet and outlet temperatures, thus showing data and software are reliable for this research. Further in- depth research were suggested on various types of soil and surface treatment and researcher wishes to generate interest among the community in adopting low- energy design and reduce solar heat gain, thus improving EAHE performances.

ملخص البحث

يهدف هذا البحث في تحري مدى تأثير التربة المبردة على فعالية مبدلة حرارة الهواء الأرضية(EAHE) الموضعة داخل البنايات في ماليزيا التي مناخها يدرك الحرارة والرطوبة طوال السنة. استعملت EAHE في دول شتى قصد تبريد البنايات، غالبا ما يكون الجو معتدلا أو حارا وقاحلا حيث درجة الحرارة النهارية مرتفعة. ومع ذلك، في ماليزيا، مصادر الدراسة عن استعمالها لهذه المبدلة ترد بعدد قليل. لقد أجري الاختبار الميداني حول استعمال EAHE في ماليزيا سنة 2012 (سنوسي، 2012). فتمت الدراسة البارامترية بكونها جزءا من الاختبار، وخلصت إلى أن من بين العديد من المعلمات في تصميم EAHE، كانت درجة حرارة التربة التي تحيط الأنابيب هي العاملة الأكثر تأثيرا. ولذلك، يقارن هذا البحث نسق EAHE المدفون تحت الأرض بين ثلاثة حالات سطح التربة المخلتفة؛ التربة العارية المعشبة القصيرة، والمظللة بالمنصات الخشبية المعاد تدويرها، والمعزولة باستخدام العجلة المعاد تدويرها. ويتألف منهج الدراسة من المعطيات المتلقى عنها من التربة التي تقاس لمدة شهر في موقع الاختبار ثم تحاكي ضمن برماجية الطاقة الزائدة للحصول على الفرق في درجة الحرارة بين ما هو المدخل (المحيط) والمنفذ (للبناية). فثبتت الدراسة أن التربة المعزولة باستخدام العجلة المعاد تدويرها في عمقها 1.0 مترا سجلت أدنى درجة الحرارة المنفذ بين الجميع مع 26.708 ^{O}C على الأقل حتى 27.172 ^{O}C . في آخر المطاف، أظهرت النتائج اختلافات ملحوظة بين درجة الحرارة المدخل والمنفذ، وإلى هذا الحد، المعطيات والبرمجيات الموثوقة لقيام هذه الدراسة. واقترحت بعد ذلك إجراء المزيد من الدراسات المتعمقة على أنواع التربة المتباينة و معالجة سطوحها، كذلك الدارس يرغب في إثارة الاهتمام في أوساط المجتمع في تبني تصميم منخفض الطاقة وتقليل اكتساب الحرارة الشمسية، وبالتالي تحسين أداء EAHE.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standard 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

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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.

Aidil Azlan Bin Ahmad Zamri

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

ISLAMIC INTERNATIONAL UNIVERSITY MALAYSIA

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Affirmed by Aidil Azlan Bin Ahmad Zamri

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

To Maimunah, Zamri, Akma, Zara

All The Dua'

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CHAPTER ONE

INTRODUCTION

Energy consumption in Malaysia is expected to keep on rising, based on previous indicators, which has becoming stakeholder's major concerns (Ong, Mahlia, & Haji Hassan, 2011). Figure 1.1 presents Malaysia energy production from year 1971 to year 2011, where the increment of energy production was influenced by the energy demand in Malaysia. The graph pattern shows that the energy production keeps increasing over the years, due to the energy demand [International Energy Agency, 2011].

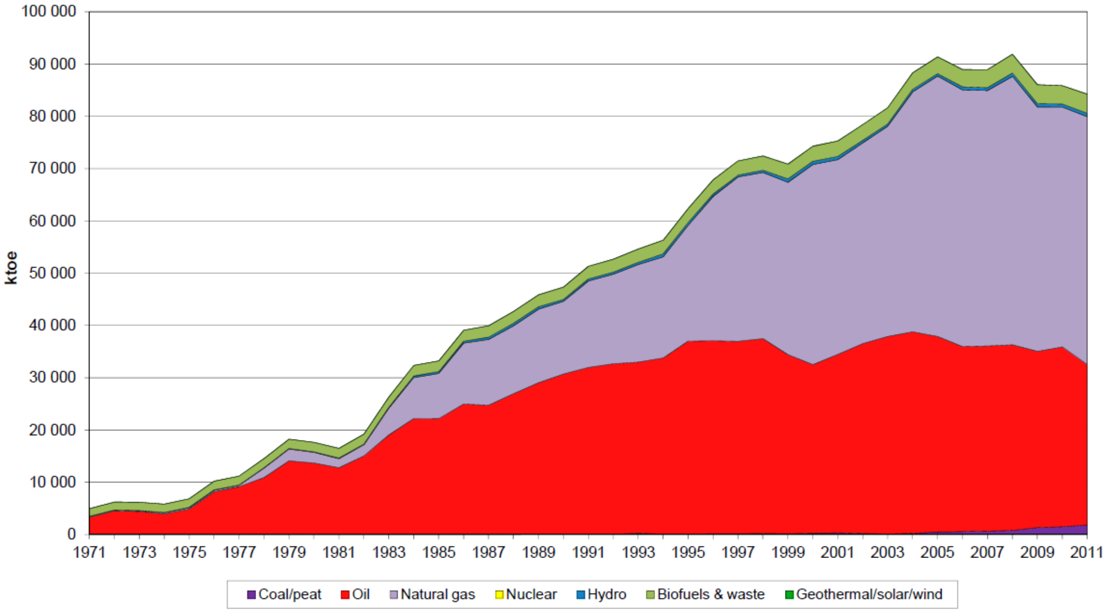

Figure 1.1: Energy produced against year according to fuel type in Malaysia. [International Energy Agency, 2011]

According to Saidur and Masjuki (2007) energy used in office buildings are 10-to 20 times more compared to the residential sector. Building sector, which consist of residential and commercial buildings consumed approximately 48% from supplied electricity (Saidur & Masjuki, 2007). On top of that, commercial buildings in Malaysia consumed about 40% of the energy supplied for space cooling due to Malaysia's hot and humid climate (Asia Pacific Research Centre, Japan, 2006). This shows that almost half of the energy consumed by a commercial building are for space cooling. The energy demand is increasing especially for commercial building as shown in Figure 1.2 (Saidur & Masjuki, 2007).

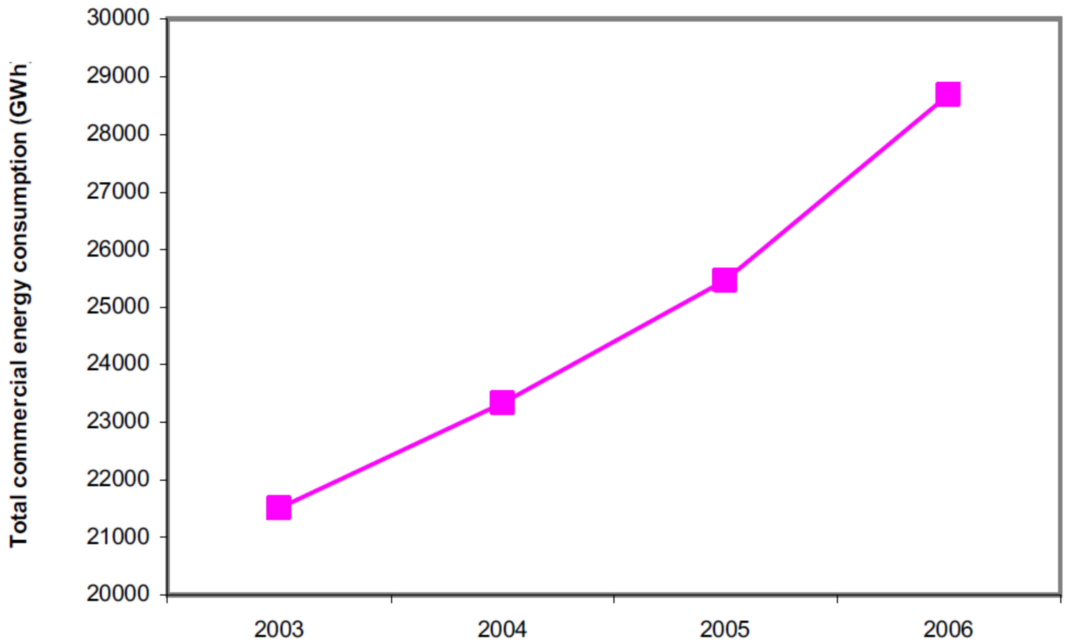

Figure 1.2: Energy consumption for commercial section's trend in Malaysia (Saidur & Masjuki, 2007)

Buildings in Malaysia are exposed to hot and humid climate and hence, depend on air conditioning for building cooling. The air conditioning demand is found in offices, houses and modern buildings with extensive glass facade. Research from Saidur and Masjuki (2007) have also found that air- conditioning devoted 57% energy compared to other appliances in a commercial building (Table 2.1). The demand of air-conditioning to provide indoor air cooling has increased, which has contributed to the increment of energy consumption in Malaysia.

Table 1.1
Total energy consumption by equipments with their distribution in percentage breakdown (Saidur & Masjuki, 2007).

Equipment/appliances	MWh/yr	% contribution
Air-conditioning	72819	57
Lighting	24273	19
Lift and pump	22995	18
Others	7665	6

In July 2009, Malaysia has come out with a green building policy and in response to that many building designers have applied passive or low energy cooling technology in Malaysia (Chua & Oh, 2011).

Researchers are carrying out studies on low energy cooling technology and one of them is Earth-to-Air-Heat exchanger, (EAHE). The EAHE system consists of long pipe buried underground that channels air from an inlet to the pipe outlet, which provide cooled air into space. When the air channelled underground through the buried pipes, heat transfer will occur through conduction, between the air inside the pipe and the soil surrounding the pipe. When the surrounding soil is cooler than the channelled air, the soil act as heat sink and make the channelled air cooler.

1.1 STATEMENT OF THE PROBLEM

The investigation of Earth- to- Air Heat Exchanger (EAHE) system is fairly new in Malaysia. There was study a carried out by Sanusi (2012) which concluded that the best performance of an EAHE system was when the EAHE pipe was buried 1 m depth underground, where the pipe outlet temperature ranges from 26.9 ^oC to 30.0 ^oC. Many researchers in Malaysia have studied thermal comfort of occupants in a building. The research result concluded that the thermal comfort range for naturally ventilated building in Malaysia ranges from 22.7 ^oC to 33.0 ^oC depending on the air movement present. Meanwhile, the results of EAHE performance by Sanusi (2012) lies within the thermal comfort range but at the ceiling of thermal comfort range. Givoni (2008) carried out a research on EAHE system and concluded that when the soil is cooled, the pipe outlet air temperature is cooler. Nik (1986) study on the soil temperature between the open and forested condition founds that the presence of a soil forested cover is the most important modifying factor in soil temperature regime (Nik, Kasran, & Hassan, 1986). Malaysia weather has high intensity of solar radiation. Figure 1.2 shows an example of 24 hours solar radiation for Subang Meteorological Department, Malaysia. This solar radiation are absorbed by the Earth surface and heats up the soil surface and underground soil. Therefore, this study is intended to find a method to reduce the outlet temperature of EAHE further by shading or insulating the soil surface, where the EAHE pipes are buried underneath, from direct diffused solar radiation. This intention is to obtain a cooler air temperature produced by the EAHE system, which achieve the mid range of thermal comfort air temperature.

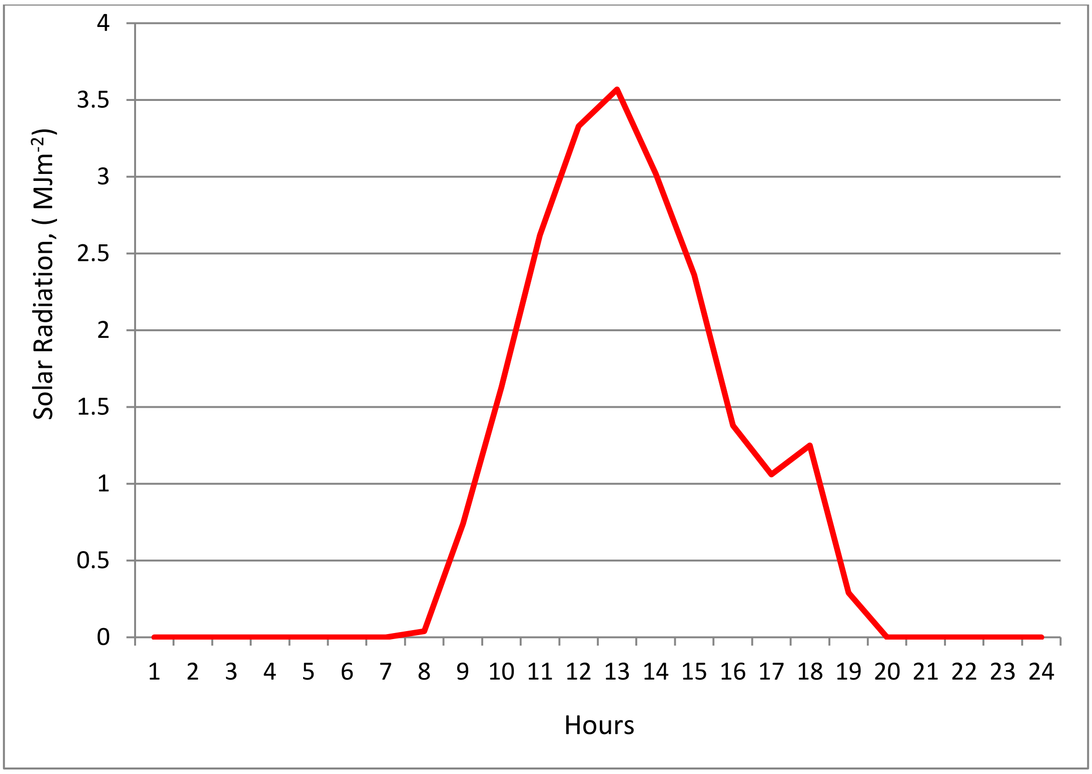

Figure 1.3: Example of one day solar radiation at Subang Meteorological Department on 2/1/2014.

1.2 HYPOTHESIS

Cooled soil can further reduce the pipe outlet temperature in an Earth-to-Air-Heat Enchanger (EAHE) system.

1.3 OBJECTIVES OF THE STUDY

This research was divided into two stages. The first stage is field work data collection of soil temperature at 1.0m and 1.5m depths underground at three different measurement areas; under bare soil surface covered by short grass; shaded soil surface by timber pallets; and insulated soil surface by recycled tyres. The second stage of the study the main part of this research, which is the parametric study of EAHE system in

Kuala Lumpur where three buried pipes buried under three different soil surface condition areas. The research is intended to achieve the following objectives:

i. To obtain soil temperature underneath three soil surface conditions; bare soil surface cover by short grass; shaded soil surface by timber pallets; and insulated soil surface by recycled tyres.
ii. To investigate on how much EAHE outlet temperature can be reduced further when the soil surface is either shaded or insulated from solar radiation
iii. To determine the most effective soil surface condition in producing the coolest EAHE pipe outlet temperature among the three buried pipes.

1.4 RESEARCH QUESTION

This research will be focused this following questions;

i. What are the soil temperature recorded below 1.0m and 1.5m with three soil surface treatments; bare soil with short grass, shaded by timber pallet and insulated by tyres?
ii. How much reduction of the outlet temperature by using EAHE when soils are treats under wooden pallets and insulate by used tyres?
iii. What is the most effective soil surface treatment in producing the coolest EAHE outlet?

1.5 SCOPE OF THE STUDY

This study comprises of both theoretical and empirical framework. The theoretical data are presented in Literature Review Chapter, whereas the empirical data are presented in the Results Chapter. The investigation was carried out in two stages; Stage 1 was a field investigation on soil temperature under three different soil surface cover. This field investigation was conducted in International Islamic University Malaysia (IIUM) Gombak. A parametric study on the EAHE system performance under three different soil surface cover was carried out using simulation software called Energy Plus in Stage 2. The field data was used in the software for EAHE parametric study.

1.6 SIGNIFICANCE OF THE STUDY

This study increases the understanding of EAHE technology and its potential to solve energy demand in Malaysia. While the EAHE technology has been successfully implemented in temperate and, hot and arid countries, the EAHE technology is further developed in this research to make the system feasible for application in hot and humid climate countries.