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Seeking Underground for Potential Heat Sink in Malaysia for Earth Air Heat Exchanger (EAHE) Application

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ABSTRACT

Prior to the exploration of technology for thermal comfort in Malaysia, this study investigates Malaysia soil temperature to demonstrate the potential of applying the technology in Malaysia. This preliminary investigation is significant since the EAHE technology utilizes the underground earth soil as a heat sink in warm climate countries.The EAHE technologyhas been applied successfully for cooling means in various building typologies in temperate as well as hot and arid countries. However, there is little published data on EAHE operation in hot and humid countries such as Malaysia. The main factor that could give positive result to EAHE cooling technology is the temperature difference between ambient and soil temperature. This paper presents measurements of air temperature and soil temperature at various depths up to 5m underground in a month of October and November in Kuala Lumpur. The field measurement was extended further measuring soil temperature at shallow depths in one year, measuredonthe same site. The result shows that at 1 meter underground, the soil temperature is approximately 7oC lower than the maximum air temperature, which was 34oC. Therefore, used properly in appropriate application, the EAHE cooling technology may be economically significant in a period with escalating energy cost and global warming.

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INTRODUCTION

In 2007, a survey finding was reported in *The Star* that Putrajaya, the youngest county of Malaysia has become another Urban Heat Island (UHI) with scorching air temperature that goes up to 40^{o}C. This maximum air temperature is found to be 5^{o}C higher than other cities in Malaysia (The Star, 2007). In Malaysia, this air temperature is considered to be extreme since the usual average temperature range is between 21.5^{o}C to 36.1^{o}C (Malaysia Meteorological Services).

The environment as a whole in the urban context is influenced by many factors, which are categorized in microclimate, natural environment and built environment. Microclimate consists of the sun, humidity, rain and wind. Natural environment consists of the topography, vegetation and existing toxins. Built environment consists of built structure, traffic and energy and infrastructure systems. However, the rise in air temperature is usually caused by the lack of natural environment and the improper design of built environment. As the air temperature increases, buildings users will resort to air-conditioning for thermal comfort, which escalates the country energy consumption even more. A report stated that air-conditioning consumes 64% of the total energy consumed in a typical office (Chan, 2004). Among various green and low energy cooling technology, Earth Air Heat Exchanger cooling technology has been successfully applied for building cooling in many countries. Therefore, this study investigates the potential of applying the Earth Air Heat Exchanger (EAHE) cooling technology in buildings in Malaysia by measuring its soil temperature underground.

The EAHE cooling technology utilizes soil as a heat sink where heat from ambient air is dissipated to via a buried pipe, through conduction. The buried pipe then transported the cooled air into the building spaces. The efficiency of EAHE cooling technology is largely influenced by temperature difference between its ambient and soil temperature, followed by air velocity of air in the buried pipe, pipe length and pipe diameter. As mentioned earlier, many researchers have explored the EAHE cooling technology as cooling means for various types of buildings in temperate countries as well as hot and arid countries. The air drawn from the EAHE pipe is found to be lower than the ambient air temperature during cooling seasons.

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In temperate countries, the technology has shown significant and positive results in experiments (Santamouris *et al.*, 1995; Solaini *et al.*, 1998; Ghosaland Tiwari, 2006; Thanu *et al.*, 2001). The technology also performed positively with significant results in experiments carried out in hot and arid country. Their results had proven that the optimum burial depth where the EAHE pipes are to be buried is 4m.

An experiment on EAHE cooling technology was carried out in Milan (Solaini *et al.*, 1998). The air temperature during summer ranges between 15^{o}C to 37^{o}C and the result of EAHE cooling ranges between 22^{o}C to 30^{o}C, which gives 7^{o}C air temperature reduction.

In 2006, the result of Ghosal and Tiwari(2006) experiment in India showed a reduction of 5^{o}C to 6^{o}C in air temperature inside the greenhouse, while the inside air temperature without EAHE cooling technology could exceed 45^{o}C. In Thanu *et al.* (2001) experiment in India, a brick tunnel is buried at 4m underground where the soil temperature is 26^{o}C. During the summer season, ambient air temperature ranges between 28^{o}C to 47^{o}C and with the Earth Tube Cooling system, the temperature is reduced to a range of 25^{o}C to 31^{o}C. However, the experiment was also carried during monsoon season, a similar climate to Malaysia. Its ambient temperature ranges between 26^{o}C to 32^{o}C and with Earth Tube Cooling system, the air temperature is reduced to a range of 25^{o}C to 31^{o}C. The result shows a less significant 1^{o}C reduction in temperature, which the author finds it negligible.

A study concluded from various findings, at 4m deep below ground, soil temperature is fairly stable and is approximately equivalent to the average of the annual air temperature (Best Practice Programme). However, this study investigates the Malaysia soil temperature up to 5m depth underground.

Statement of Problem:

The result from Thanu *et al*. (2001) experiment, carried out in similar climate to Malaysia, creates a challenge to this study. Therefore, this study evaluates the potential of applying Earth Tube Cooling technology in Malaysia climate before implementing it. Since soil temperature is the main factor in achieving significant results, the knowledge of Malaysia soil temperature is essential. Currently there is no record of soil temperature data of Malaysia ground at 5 meter deep. Data of Malaysia earth temperature is available from the Malaysia Meteorology Department. However, these are daily data collected at a maximum depth of 1 meter below ground.

Objective:

Due to lack of information on Malaysia soil temperature, the intial goal is to obtain soil temperature data at various depths up to 5m deep below ground. The purpose of this study is also to analyze the potential of EAHE cooling technology application in Malaysia climate with reference to its soil temperature and ambient temperature. The various depth measurements also help to determine the optimum depth in which the EAHE pipe should be buried to get optimum results.

Methodology:

Field Experiment Site:

The soil temperature measurement was carried out on a site located within the International Islamic University campus in Malaysia. The soil is sandy and barely covered by short grass. Hence, it is exposed to solar radiation during the day.

Measurements:

The measurements were carried out in two stages; the first up to 5m depth underground, followed by the second stage focusing more on the shallow depths. The field investigation includes measurements of outdoor dry bulb temperature (DBT), ground surface temperature and soil temperature at 1m, 2m, 3m, 4m and 5m deep below ground. The measurements were logged from the 5th of October to the 14th of November 2007 using one thermocouple wire for each measurement, which were all connected to a multi channel data logger. Readings were taken at 10 minutes interval for a period of approximately one month. The result of the first stage field experiment is analyzed and due to the finding of first stage field experiment, which is shown in the next chapter, the second stage field experiment measured soil temperature at 0.5m, 1.0m and 1.5m and data was logged for one year.

Results:

The results of the first stage field experiment are divided into weekly graphs. Figure 1 to 4 show the temperature pattern for all measurements from 17 October to 14 November 2007. During this period, the outdoor DBT ranges from 22.0^{o}C (at 6:00 in the morning) to 33.5^{o}C (at 12:00 in mid-afternoon). In the year 2006, the outdoor DBT ranges from 21.9^{o}C to 34.8^{o}C and it's annual average outdoor DBT is 27.2^{o}C (Malaysia Meteorological Services).

Figures 1 to 4 show that the temperature pattern of data measured 1m below ground is fairly stable with temperature similar to the annual average outdoor DBT of Malaysia weather. The figures also show from 1m below ground, the soil temperature increases with depth up to about 5m, where the values are very close to that of 4m below ground.

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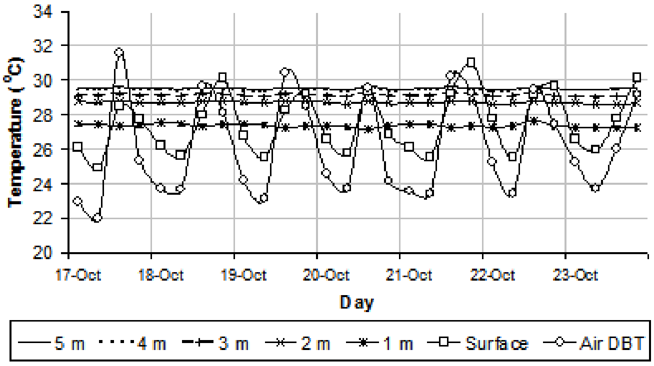

Fig. 1: Temperature patterns in week 1.

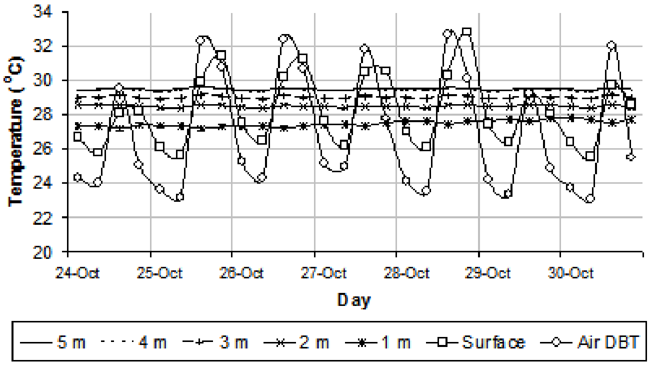

Fig. 2: Temperature patterns in week 2.

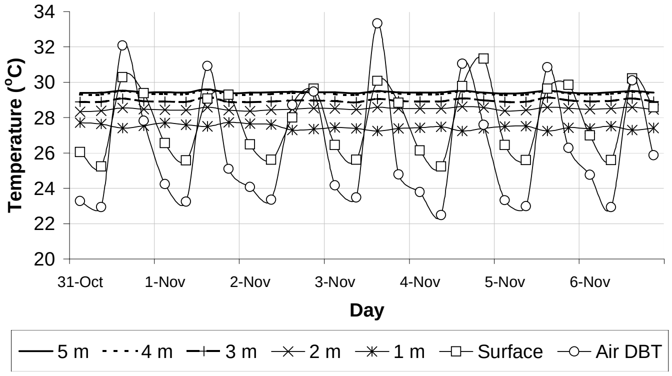

Fig. 3: Temperature patterns in week 4.

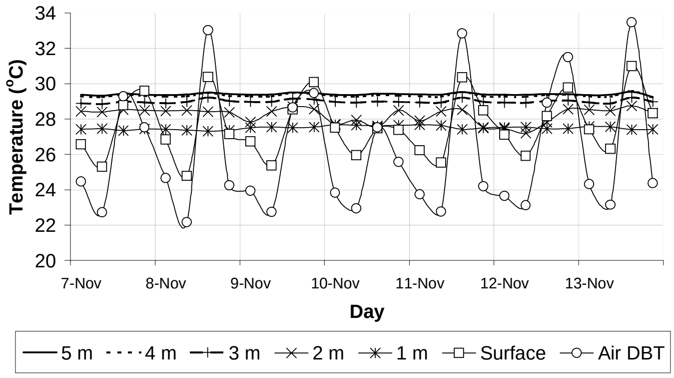

Fig. 4: Temperature patterns in week 3.

Figure 5 shows the average temperatures of air, and soil at 0.5m, 1.0m and 1.5 m depths underground.

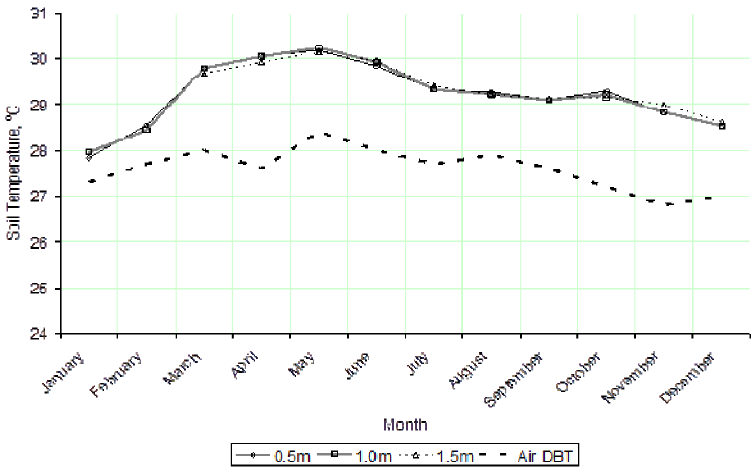

Fig. 5: Average air temperature and soil temperature at 0.5m, 1.0m and 1.5m depths underground

In a year, the soil temperature at 0.5m depth ranges from26.6^{o}C to 30.7^{o}C, at 1.0m depth ranges from 27.2^{o}C to 30.5^{o}C and at 1.5m depth ranges from 28.5^{o}C to 30.3^{o}C. The average monthly soil temperature are similar for the three depths, however, there is slight difference in the annual amplitude of the soil temperature. The results show that the deeper the soil, the amplitude decreases. Eventhough the average air temperature are lower than the average soil temperature at the three depths, the maximum soil temperature at these depths are at least 5^{o}C lower than the maximum air temperature.

Conclusions:

This study is an initial investigation of evaluating the potential of Malaysia soil to act as a heat sink in Earth Tube Cooling technology to provide cooling for building. The results has shown that there is potential of applying the EAHE cooling technology in buildings in Malaysia, particularly when the air temperature increases beyond 34^{o}C. The temperature patterns have shown that the optimum depth for locating the Earth Tube Cooling in Malaysia soil would be at 1m below ground. The temperature difference between the maximum outdoor DBT and soil at 1m below ground is approximately 7^{o}C. Although the temperature difference is not very significant, the cooling technology could be economically significant during the current situation of global warming and rising energy cost. This initial investigation gives opportunity for further study as such:

1. Earth Tube Cooling technology coupled with night-time natural ventilation for more significant results.
2. Reduce soil temperature to the minimum outdoor DBT, by applying the method of shading or insulating the soil from direct exposure to solar radiation(Givoni, 2007).

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