THE POTENTIAL OF LOW ENERGY EARTH PIPE COOLING IN HOT AND HUMID MALAYSIA

Aliyah N. Z. Sanusi[1], Li Shao[2] and Najib ibrahim[3]

ABSTRACT
This paper presents a study on the performance of Low Energy Earth Pipe Cooling in Malaysia which has hot and humid climate throughout the year. The increasing demand of air-conditioning for cooling purposes motivates this investigation in search for better cooling alternative. The passive technology, where the ground was used as a heat sink to produce cooler air, has not been investigated systematically in hot and humid countries. Therefore, in this work, air and soil temperatures were measured on a test site in Kuala Lumpur. At 1m underground, the result is most significant, where the soil temperature are 6^{o}C and 9^{o}C lower than the maximum ambient temperature during wet and dry season, respectively. Polyethylene pipes were then buried around 0.5m, 1.0m and 1.5m underground and temperature reduction between inlet and outlet were compared in two different seasons; wet and dry seasons. A significant temperature reduction was found in these pipes: up to 6.4^{o}C and 6.9^{o}C depending on the season of the year. The results have shown the potential of Earth Pipe in providing low energy cooling in Malaysia. The temperature reduction is enough to help reduce escalating energy consumption in Malaysia.

Keywords: Soil temperature, tropical Malaysia, Earth Pipe Cooling, Low Energy Cooling

INTRODUCTION
This research was intended to seek for a better cooling system in terms of sustainability than air-conditioning, which has contributed significantly to the vast increment in energy consumption in Malaysia. The current energy issue was tackled in this research by conducting an investigation on passive earth pipe cooling technology at an experimental site in Malaysia.

Earth pipe cooling technology works as a passive cooling system that utilizes the soil underground as a heat sink. In the system, ambient air is channeled through pipes, which are buried underground.

[1] Lecturer, Department of Architecture, Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia.
[2] Professor, Head of Research, Institute of Energy and Sustainable Development, De Montfort University, Leicester, United Kingdom.
[3] Professor, Department of Building Technology and Engineering, Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia.

This earth pipe cooling technology has been explored by many researchers and used by building designers as cooling means for various building types in temperate countries as well as hot and arid countries, where the results have been significant and positive (**Ghosal and Thiwari, 2006; Santamouris et al., 1995; Solaini et al., 1998; Thanu et al., 2001**). Previous investigations found the optimum depth to bury the pipe is rather great, at 4m underground in many cases. However, for Malaysia climate, this optimum depth needs to be investigated again.

Statement of Problem

In a typical office in Malaysia, 64% of the energy consumed was for air-conditioning (**Chan, 2004**).

Research Objective

The research aim objectives were first to obtain soil temperature data at test site in Kuala Lumpur for various depths. This followed by to determine the optimum setup for buried pipe. The third objective was to ascertain air temperature reduction performances of buried pipe.

Malaysia Weather

Figure 1 Trend of monthly absolute maximum dry bulb temperature from the year 2002 to 2006 in Kuala Lumpur, Malaysia.
*(**Source**: Meteorology Department, 2007)*

Figure 1 shows the trend of monthly absolute maximum dry bulb temperature within 5 years. Malaysia experiences warm and humid weather throughout the year, comprising of wet season from October to December and hot/dry season in from May to June. The air temperature normally ranges from 21.5^{o}C to 36.1^{o}C.

Figure 2 shows the rainfall trend within 5 years. It is shown that within that 5 years, the weather is dry mostly in May and June but turns to wet at the end of the year in most years.

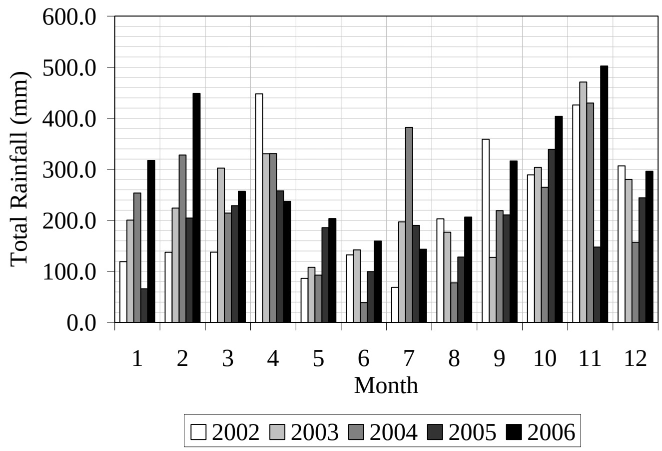

Figure 2 Monthly total rainfall in five years from 2002 to 2006.
*(**Source**: Meteorology Department, 2007)*

Literatures regarding Malaysia thermal comfort zone have been reviewed and found that for naturally ventilated building, occupants felt comfortable in temperature ranges from 22.7°C to 31.6°C. Among the findings from various researches on Malaysia thermal comfort zone for naturally ventilated buildings, the average of the upper limit of the comfort zone is found to be 30.1°C.

METHODOLOGY

With the basic knowledge of Earth Pipe Cooling, Malaysia weather and Malaysia comfort zone, a research methodology was formed. Field experiments became the main investigation of this research. It is divided into two interrelated field investigations; soil temperature measurement and Earth Pipe Cooling experiments.

Research Limitation

The fact that challenges the Earth Pipe Cooling experiment in Malaysia is that there is no systematic record of Malaysia soil temperature hourly data at up to 4m depth underground. Furthermore, there were very few records of Earth Pipe Cooling Technology being used in Malaysia or other hot and humid countries.

Experiment Site

The site is located within the International Islamic University Malaysia (IIUM) campus in Kuala Lumpur, Malaysia. It is in an exposed space and the ground is covered with short grass. Very few trees are found scattered around the site (Figure 3).

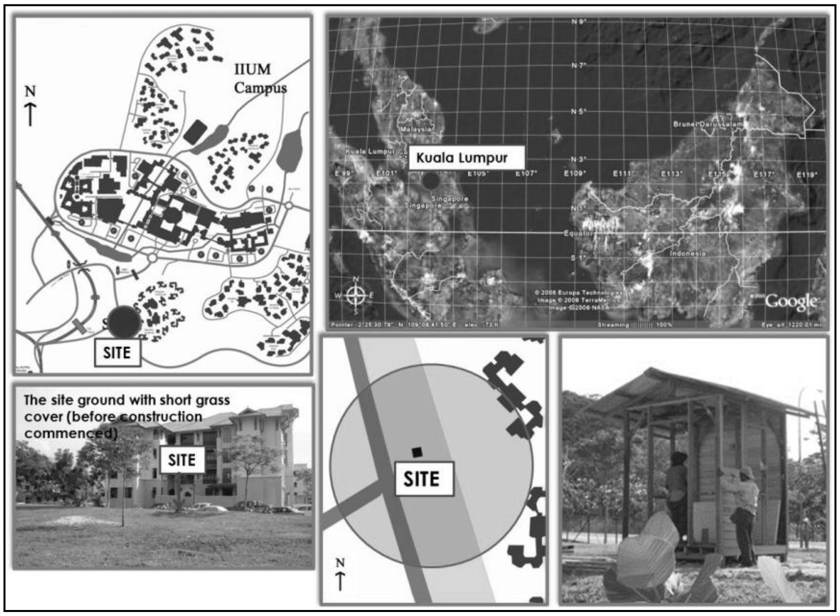

Figure 3 Location of experiment site and site condition.
*(**Source**: Google map, 2007, IIUM Development Division, 2007 and Sanusi, 2012)*

Soil Temperature Measurement

An initial investigation on soil temperature measurement was carried out during the wet season, in October and November, when the weather is cooler. It comprises of outdoor dry bulb temperature, ground surface temperature, and underground soil temperature at 1m, 2m, 3m, 4m and 5m depth.

Soil temperature measurement was conducted again focusing on the soil around 1m depth, which the data taken was outdoor dry bulb temperature and soil temperature at 0.5m, 1.0m and 1.5m underground. The second soil temperature measurement was conducted for approximately one year duration.

Earth Pipe Cooling Experiment

The Earth Pipe Cooling Experiment is divided into three sets of investigations. The first two investigations were conducted in two different seasons; wet and hot and dry. In both seasons, based on the results obtained in soil temperature measurement, Earth Pipe Cooling experiment was conducted with three 3” polyethylene pipes buried separately, at 0.5m, 1.0m and 1.5m deep underground. All the pipes are 30m long. There is a fan blower connected to all pipe inlets, which provides air flow into the buried pipes at 5.6m/s. The fan was switched on daily from 10am until 6pm to allow night ventilation. The pipe inlets and outlets are sheltered by an experimental shed (Figure 4), which has 2m x 2m x 2m dimensions. Data of each buried pipes were recorded for 48 hours at 10 minutes interval. The tests were carried out in sequence rather than in parallel to avoid thermal interference between the pipes.

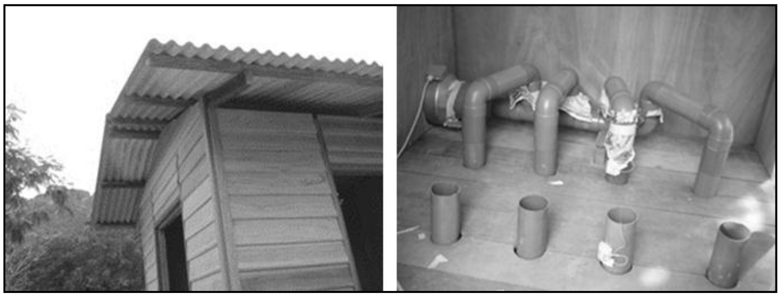

Figure 4 Pictures of the experiment shed and its inside view showing the exposed buried pipe outlet.
*(**Source**: Sanusi, 2012)*

Table 1 and Figure 5 shows the equipment used during the field investigation of soil measurement and Earth Pipe Cooling experiment.

Table 1 List of equipment used during field investigation

Figure	**Equipments**	**Functions/Measurements**	**Units**
5 (a)	Fan Blower	Supply air flow	
5 (b)	USB TC-08 Thermocouple Data Logger with 7 K-type thermocouple wires	Soil and air dry bulb temperature	^{o}C
5 (c)	HOBO Pendant Temp Logger (UA-001-64)	Dry bulb temperature	^{o}C
5 (d)	HOBO U12-012 Temp/RH/Light/Ext	Dry bulb temperature/relative humidity	^{o}C/%
5 (e)	HOBO External Sensor TMC6-HD	Dry bulb temperature (initially measure buried pipe inlet/outlet)	^{o}C
5 (f)	Air Flow Meter from Testo	Air velocity	m/s

*(**Source:** Sanusi, 2012)*

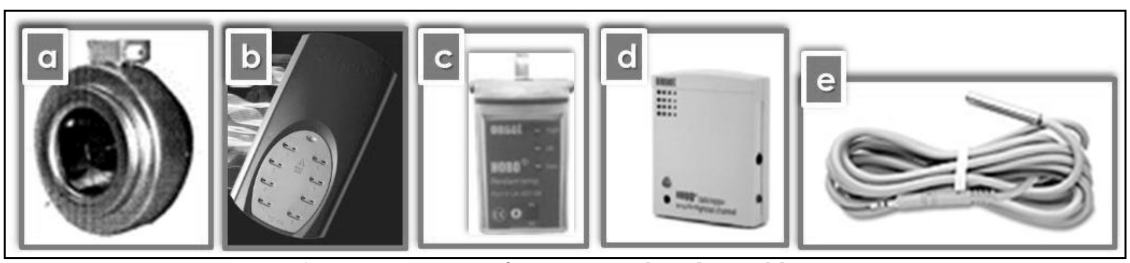

Figure 5 Pictures of equipments listed in Table 1.
*(**Source**: Sanusi, 2012)*

RESULTS

All field data results were compiled into two main interrelated investigations; the soil temperature measurement and Earth Pipe Cooling experiments.

Soil Temperature Measurement

The result of soil temperature measurement has shown possibility of making the soil underground as heat sink to reduce extreme solar heat gain especially during 1200 hours to 1400 hours of the day. Figure 6 shows the results obtained from the initial ambient air and soil temperature measurement during the wet season in October 2007.

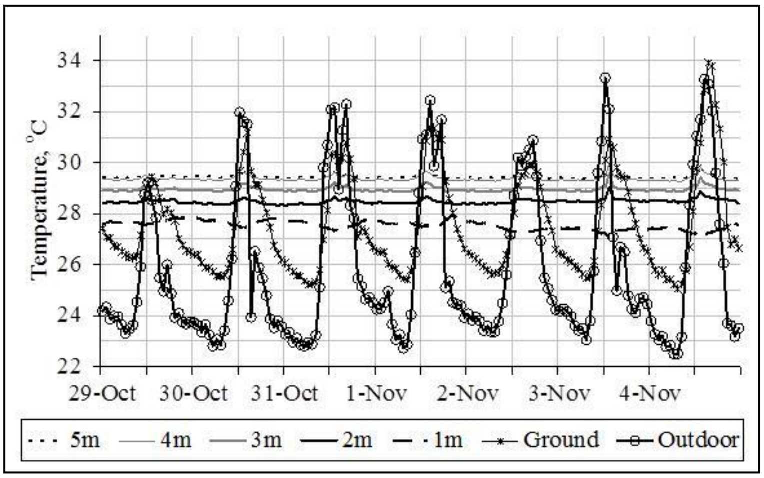

Figure 6 Ambient air and ground soil temperature and underground soil temperature at 1m, 2m, 3m, 4m and 5m depths.

*(**Source**: Sanusi, 2012)*

Referring to Figure 6, it is shown that the soil temperature is fairly stable at 1m depth underground with reduced daily amplitude compared to the ground level soil temperature. It also shows that the soil temperature increases with increasing depths underground and the soil temperature changes a little beyond 4m deep underground.

Figure 7 presents result of soil temperature measured at 0.5m, 1.0m and 1.5m depth underground, which were measured for approximately one year.

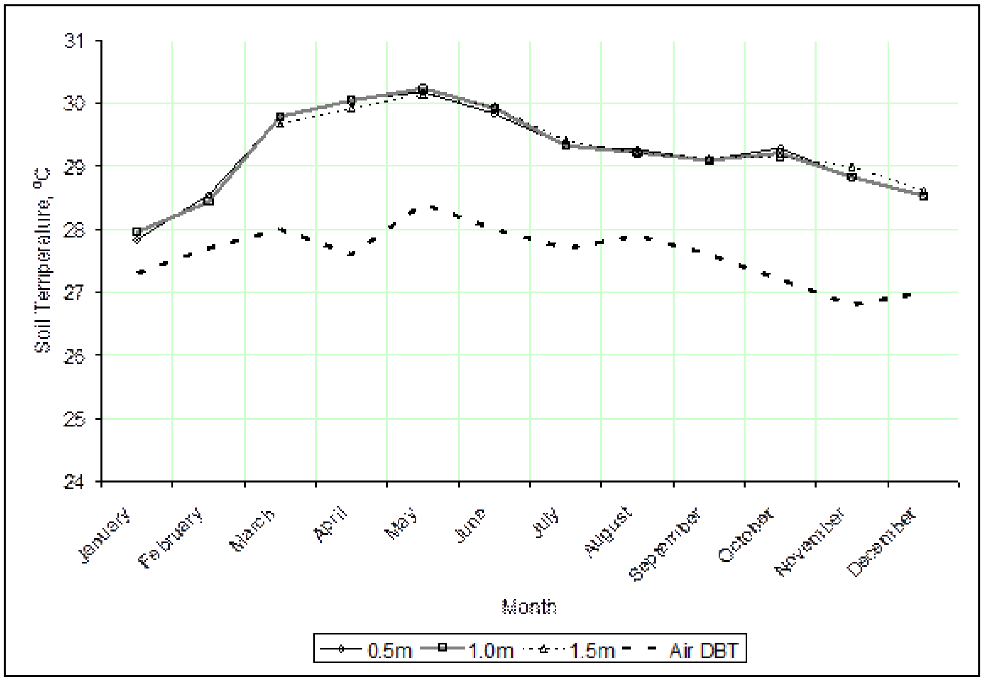

Figure 7 Monthly average of ambient air and underground soil temperature at 0.5m,1.0m, 1.5m, depths at Gombak, Kuala Lumpur.
*(**Source**: Sanusi, 2012)*

Figure 7 shows that in one year measurement, the soil temperature at 1m depth fluctuates but it takes advantage of the cool temperature in the wet season.

Earth Pipe Cooling Experiments

Throughout the Earth Pipe Cooling experiment, it is evidently that temperature reduction does occur within the inlet and outlet of the buried pipes. Figure 8 shows results obtained during the wet season.

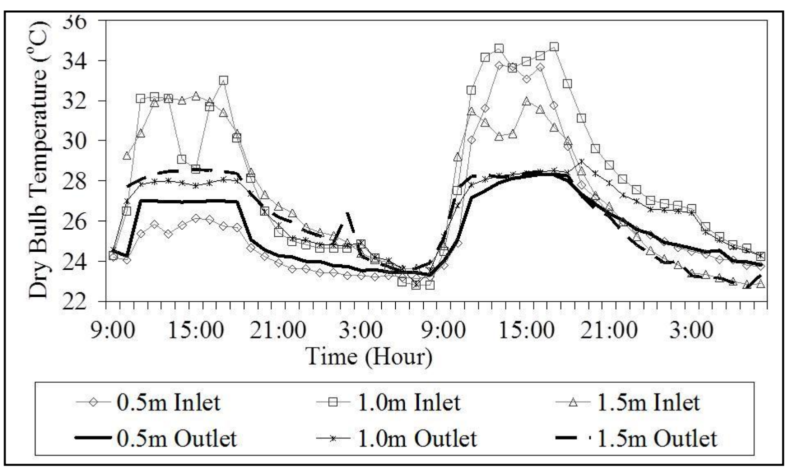

Figure 8 Results of pipe inlet and outlet during the wet season.
*(**Source**: Sanusi, 2012)*

In the wet season, max temp drop through the buried pipe was 6.4^{o}C (in 1m depth buried pipe). Figure 9 shows results obtained from field experiment during the hot season. In the dry season the max temperature drop was found to be 6.9^{o}C (in 1m depth buried pipe)

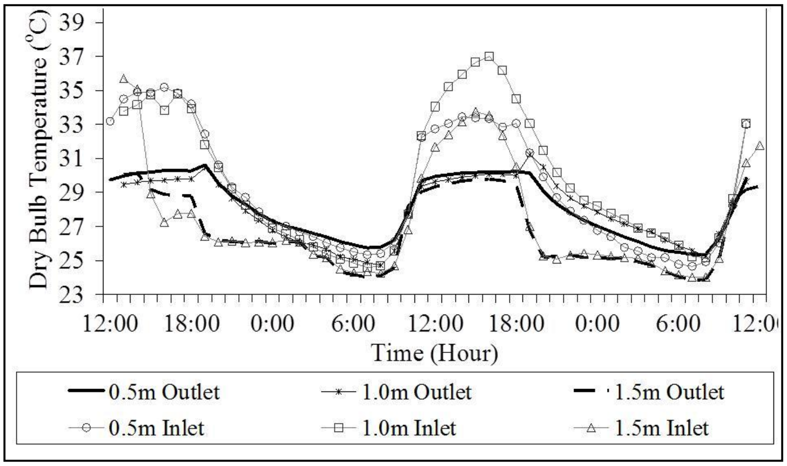

Figure 9 Results of pipe inlet and outlet during the hot season.
*(**Source**: Sanusi, 2012)*

By relating Figure 8 and 9 to Figure 7, it is shown that the buried pipe outlet temperature is influenced greatly by the respective soil temperature during both the wet and the hot and dry seasons.

CONCLUSION

In conclusion, the research objectives were achieved through research findings. The first finding shows that soil temperature is found to change a little beyond the depth of 4m, which is between 29.3^{o}C and 30.2^{o}C. Secondly, 1m depth underground is shown to be the optimum burial depth. Finally, in both wet and hot and dry seasons, there is evident of significant temperature reduction found in all buried pipes at 0.5m, 1.0m and 1.5m depth underground. The maximum temperature reduction was found to be 6.4^{o}C and 6.9^{o}C depending on the season of the year. Among three buried pipes, the maximum temperature reduction was found at 1m depth buried pipe in both seasons.

RECOMMENDATION FOR FUTURE RESEARCH

Due to significant differences in buried pipe outlet temperature between wet season and hot and dry season, a one year investigation of Earth Pipe Cooling experiment can be a valuable investigation to see the whole year weather condition influence on the performance of Earth Pipe Cooling system buried at 1m depth.

The field investigation findings show similarity in average between the buried pipe outlet temperature and the relative soil temperature in both the wet and hot and dry seasons.. This demonstrates the high influence of soil temperature on the performance of

Earth Pipe Cooling Technology. This suggests the treatment of the soil, having it shaded from the daytime solar radiation with either plantation or lightweight structure.

According to a study by Givoni, as mentioned in Chapter 3, shaded soil has lower average temperature. Since the soil temperature affect the pipe outlet temperature, a lower soil temperature could reduce the pipe outlet temperature even more than recorded in this research finding.

ACKNOWLEDGEMENTS

I would like to express sincere gratitude to the International Islamic University Malaysia (IIUM) and De Montfort University for funding the research work and providing useful equipments. Thank you to the Development Division of IIUM for the permission of using IIUM land for my experiment setup. Thank you also to my research assistant, Nik Azmin Riza Nik Ahmad for his full dedication.

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