EFFECT OF DIFFERENT TYPE OF SOIL IN EFFICIENCY OF THERMAL REDUCTION IN EARTH AIR HEAT EXCHANGER (EAHE)

NOR AZIMAH BINTI MOHD NOR'AINI

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ABSTRACT

Earth Air Heat Exchanger (EAHE) had shown to provide an effective and economical approach in reducing indoor building temperature as well as reducing electricity consumption and carbon dioxide emission. As an earth coupling, EAHE is designed to indirectly cool or heat buildings by ventilating outdoor air through a single or series of pipes buried underground. The efficiency of EAHE systems depend upon several factors, namely type of pipes, mineral compositions and the thermal conductivity of surrounding soils. Studies in the past have indicated that, different in temperature reduction were observed at different countries where the EAHE have been installed, primarily due to the effect of soil type. This study determines the efficiency of a simple, small scaled EAHE system by burying single pipe into different type of soil. Two soils were considered namely, original soil and crushed aggregate soil containing high quartz mineral content. The results indicated that a maximum temperature reduction of 7.5°C was achieved when the pipe was surrounded by crushed aggregate whereas; a much lower reduction of 3.8°C was observed for the natural soil. This study clearly shows that soil type plays a significant role in determining the efficiency of an EAHE system.

ABSTRAK

Sistem pengudaraan penukaran haba bumi (EAHE) telah menunjukkan ia menyediakan satu pendekatan yang berkesan dan ekonomi dalam mengurangkan suhu bangunan dalaman serta mengurangkan penggunaan elektrik dan pengeluaran karbon dioksida. Sebagai gandingan bumi, EAHE direka untuk bangunan langsung sejuk atau haba oleh pengalihudaraan udara luar melalui satu atau siri paip dikebumikan di bawah tanah. Kecekapan sistem EAHE bergantung kepada beberapa faktor, iaitu jenis paip, komposisi mineral dan aliran haba tanah sekitarnya. Kajian pada masa lalu telah menunjukkan bahawa, berbeza dalam pengurangan suhu diperhatikan di negara-negara yang berbeza di mana EAHE telah dipasang, terutamanya disebabkan oleh kesan jenis tanah. Kajian ini menentukan kecekapan yang kecil sistem EAHE mudah, berskala dengan menanam paip tunggal ke dalam jenis tanah yang berbeza. Dua tanah iaitu, tanah asal dan agregat tanah dihancurkan mengandungi kandungan mineral kuarza tinggi. Keputusan menunjukkan bahawa pengurangan suhu maksimum sebanyak 7.5 °C dicapai apabila paip dikelilingi oleh agregat hancur sedangkan; pengurangan yang lebih rendah sebanyak 3.8 °C diperhatikan untuk tanah semula jadi. Kajian ini jelas menunjukkan bahawa jenis tanah memainkan peranan penting dalam menentukan kecekapan sistem EAHE.

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing Material
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
BS	British Standard
CFC	Chlorofluorocarbon
CO_2	Carbon Dioxide
EAHE	Earth air heat exchanger
et al.	Latin phrase et alia, which means "and others"
i.e	Latin phrase id est, which means "in other words"
PVC	Poly Vinyl Chloride
UMP	Universiti Malaysia Pahang
XRD	X-ray Diffraction

CHAPTER 1

INTRODUCTION

1.1 Background

Global warming is the increase of Earth's average surface temperature due to effect of greenhouse gases(Preining, 1992). Greenhouse gases basically consist of water vapour, carbon dioxide, methane nitrous oxide, ozone and Chlorofluorocarbon (CFC) (Ritzkowski and Stegmann, 2007 ; Krupa, 1989). Currently, the amount of carbon dioxide in the atmosphere has increased by 35% since the Industrial Revolution. The actual concentration of carbon dioxide in fact is now higher than at any point in the past 650,000 years (Schneider, 2008). The increase in carbon dioxide concentration caused the sun radiation to become trapped and inevitably leads to the increase in the earth's temperature (Florides *et al.*,2010). In other words, the surrounding and buildings are also affected (i.e. increase in the thermal temperature)

When the temperature in a building increased, the thermal comfort level reduced significantly. Therefore, in order to overcome this problem, buildings are often designed to minimize this effect. Design of building in reducing heat includes the location of the building, material used for the building and also the ventilation system. This is to ensure circulation of air within the building and reduce the heat generated within buildings. According to Omer (2008) , 43% of thermal reduction can be achieve if well established technologies were used such as glazing, shading, insulation and natural ventilation.

Natural ventilation are the main mechanism to provide ventilation for smaller buildings. Natural ventilation from breezes can helped with the indoor airflow in a buildings but breezes are not always present. Few factors such as shapes, heights of the ceiling, depth of space with respect to ventilation openings and also location of building with respect to environmental pollution sources can improve the natural ventilation and thermal comfort in buildings (Omer, 2008).

Similarly, installation of air conditioning systems such as fans, ventilators, or air conditioner would also improve the quality of thermal comfort of buildings. The use of such appliances, however consumed high amount of electricity and power. For instance, a ceiling fan requires about 90 watt of electric source, whereas, a window unit air-conditioner requires about 1440 watt (Bluejay, 2012). Thus, the maintenance cost for keeping a building cool can be extremely expensive. It is expected that, electricity consumption and carbon emission due to building cooling are likely to increase by several-fold in the next two decades (Hitchin and Pout, 2000).

The rising concern about the global warming (i.e. climate related to carbon dioxide emissions), increasing air temperature and the increasing cost of energy consumption by using cooling systems provided, an increased number of 'passive' technique are being considered both for new houses and for retrofitting into existing ones.One of the most promising technique is the passive cooling Earth Air Heat Exchanger (EAHE) system (Ojebode and Gidado, 2012)

EAHE utilizes soil to dissipate heat from the surrounding atmosphere by circulating hot air into series of pipes or different pipe materials (Ahmed *et al.*,2007). EAHE is designed to indirectly cool or heat buildings by ventilating outdoor air through a buried duct exploiting temperature gradients between outdoor air and the earth resulting in energy savings when conditioning an indoor environment (Zhang and Haghighat, 2005). Studies in the past have shown that, EAHE can be used to increase thermal comfort in buildings and at the same time decrease carbon dioxide emission (Joen*et al.*, 2012). Although the system is practical, the efficiency of the EAHE varies from one location to another, depending upon, type of soil present within the vicinity (Ascione *et al.*, 2010). Studies on the type of soil on the thermal reduction efficiency of an EAHE system has not been carried out to date. But EAHE system gave different thermal reduction depending on the place where it was conducted.

It was noted that, different thermal reduction in EAHE system was observed in different geographical location. For instance in United Kingdom, the study indicated that the indoor temperature rises above 27℃ for more than 6 hours but after applying the system the building maintaining the temperature below 27℃ (Ahmed *et al.*, 2007). In Milan in was observed the best performance can be obtain in wet and heavy soil. Ascione et al., (2010) studies shows that even less suitable kind of soil (light and dry) allows significant savings and in terms of thermal energy, these are about 25% for Naples , 30% for Rome and 34% for Milan. Moisture content of the soil is important and gives an effect to the thermal reduction of the EAHE system. A correct contact between soil and pipe also could effect the reduction. Soil such as compacted clay or sand are suitable for correct contact in EAHE system.

A system constructed in Burkina Faso reduced the ambient temperature up to 7.5℃. The outside temperature gives the reading between 25℃ to 43℃ but the temperature using EAHE system maintain and remain at 30.4℃ (Woodson *et al.*, 2012)

In Nigeria, the climate is hot and low relative humidity . In between February and May, the daily mean maximum indoor temperatures about 37 °C with low indoor air velocity. At a given location, it is impossible to lowered down the soil temperature. But in order to cool the soil it is necessary to eliminate or minimize the heating of the soil by the sun, by shading, while enable cooling by evaporation from the earth surface (Givoni, 2007). Most of passive cooling system had been establish in Europe but not in places with hot climate because the potential to reduce the temperature is low due to higher soil temperature. However, it can be improve by using various soil cooling strategies to lower the natural subsurface soil temperature such as shading, surface irrigation, surface treatment using plants and pebbles (Givoni, 2007 ; Ahmed, 2008).

In this study, a simple small scaled EAHE system was designed and tested by burying a single pipe in two different type of soils, namely original soil and curshed aggregate cotaining high percentage of quartz mineral. The thermal reduction efficiceny of the soils with diffeent mineral compostitions is then evaluated.

1.2 Problem statement

Global warming caused the surrounding temperature to increase. To maintain an acceptable thermal comfort in buildings air condition are normally used. In order to provide a cause efficient system, EAHE is proposed to be used. Thermal reduction efficiency of EAHE system highly depend upon the soil in contact with the pipe. Thus, identifying the best soil having excellent thermal dissipation behavior might help in improving the design and performance in EAHE system.

1.3 Research objectives

The objectives of this study are:

a) To identify which of the two soil type (original soil and crushed aggregates) gives the most thermal reduction to the output temperature of the tube.

b) To determine the effect of soil type on the temperature reduction of an EAHE system.

1.4 Scope of Study

A simple pilot scale EAHE system was designed and constructed in Universiti Malaysia Pahang (UMP) Gambang. The system consists of a blower and a 2.5 m pipe buried 1.0 m underground. Two different types of soils were considered in this study (i.e. original soil and soil containing higher percentage of quartz). Temperature changes were monitored for the two types of soils considered. Comparisons were then made to determine the thermal reduction efficiency of the system.

1.5 Thesis layout

This thesis consist of 5 chapters .

Second chapter is Literature Review. This chapter present the literature review related to the study. This chapter includes global warming problem, heat management and EAHE. In EAHE, the parameters affecting the thermal reduction were stated which includes cross section of the pipe, material of the pipe, depth of the pipe and also type of soil used in EAHE.

Third chapter is Methodology. This chapter explains the methodologies adopted in this study. This chapter covers soil properties of the soil used, design of EAHE, site preparation and also temperature monitoring.

Forth chapter is Result and Discussion. Further discussions were explained in this chapter. The result of soil properties and temperature reduction tested were discussed.

Lastly is the fifth chapter which is Conclusion. The last chapter refers to the conclusion of the research.

CHAPTER 2

LITERATURE REVIEW

2.1 Global warming

The earth is becoming hotter as global warming occur. Global warming is a problem which happen cause by the everyday activities which require the burning of fossil fuels which result in carbon dioxide emission, one of the major greenhouse gases that causes global warming (Ritzkowski and Stegmann, 2007). The warming of the Earth's is called the greenhouse effect.

There are two type of greenhouse effect which are natural greenhouse effect and the other one is the man-made greenhouse effect. The natural greenhouse effect is the system which keeps the Earth's climate warm and habitable. Different to natural greenhouse, the man-made greenhouse effect is where the enhancement of Earth's natural greenhouse effect by the addition of greenhouse gases from the burning of fossil fuels such as coal and natural gas (Spencer, 2012). The greenhouse gases are include mostly the water vapor , clouds , carbon dioxide and methane. Due to human actions from burning of fossil fuels creates more carbon dioxide in atmospheric. The more carbon dioxide, the more infrared energy being trapped and this causes a warming tendency in the lower atmosphere and at the surface. Not only carbon dioxide, many fluorinated gases also have very high global warming potentials relatives to other greenhouse gases, so small atmospheric concentration can have large effects on global temperature. Hydro fluorocarbons comes from major emission source such as air conditioning system in both vehicles and buildings(Lewis, 2011).Spencer R. (2013) stated that as of 2008, it is believed that there is an enhanced of the Earth's natural greenhouse effect by about 1%. The global warming theory also mentioned that the lower atmosphere must had respond to this imbalance where less infrared radiation being lost than solar energy being absorded by causing an increase in temparature.

According to Natural Resources Defense Council, over the past 50 years the average global temperature has increased at the fastest rate in recorded history and Malaysian Meteorological Department had mentioned that an average temperature increase of 0.5°C to 1.3°C is recorded in Malaysia, when comparing the long term means obtained for 1961- 1990 and 1998-2007. The projected temperature increase in the next 30 years is between 1.0°C to 3.5°C. Increases of greenhouse gases such as carbon dioxide in the atmosphere claims to be one of the reasons of rising atmosphere temperature.

2.2 Heat management

As the earth's temperature increased, the only way to help reducing the surrounding temperature is by installing air conditioning system in a building. Air conditioning are include the fan, ventilator and also air conditioner. Air conditioner is a major for home appliance , system or mechanism designed to change the air temperature and humidity within an area and meanwhile air conditioning is the process of altering the properties of air to more favorable condition. For tropical weather such as in Malaysia, the use of air conditioning system helps to create a more comfortable living environment (Rahman*et al.*, 2007)

For a comfortable living, air conditioner can be use and nowadays, air conditioner is cheaper and sold in the market with affordable price. Therefore, Malaysians now can afford to have more than one unit of air conditioning in their homes (Rahman *et al.,* 2007). The increase used of air conditioner in a building will cause more problem rather than solving it. Air- conditioners draw electricity, and deliver a double whammy in terms of climate change, since both electricity they use and the coolants they contain result in planet-warming emissions (Rosenthal, 2012). Rahman *et al.*, (2007) also mentioned, it has become an article of faith amongst environmentalist that improving the efficiency fo energy use will lead to a reduction in energy consumption.

Energy consumption are depend on the quantity usage of air conditioner. The usage of air conditioner is related to human comfort level. Thermal comfort is important both for one's well being and for productivity. It can be achieve only when the air temperature, humidity and air movement are within range often referred to as comfort zone. Maintaining constant thermal conditions in the offices is important. Even the minor deviation from occupants attention to drift, making them restless and easily distracted (Thermal Comfort for Office Work, 2013).

According to American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Standard 55-2010, they recommended the temperature standard for office temperature are as mentioned in Table 2.1 :

Table 2.1 : Standards of office temperature (ASHRAE 55-2010)

Temperature / Humidity Ranges for Comfort			
Conditions	**Relative Humidity**	**Acceptable Operating Temperatures**	
		°C	**°F**
Summer (light clothing)	If 30%, then	24.5 - 28	76 - 82
	If 60%, then	23 - 25.5	74 - 78
Winter (warm clothing)	If 30%, then	20.5 - 25.5	69 - 78
	If 60%, then	20 - 24	68 - 75

Countries in west side have four types of season including winter and summer. Depending on the relative humidity, the acceptable operating temperatures are different.

Since Malaysia is a country which only have heat and rain, it might differ in terms of the temperature value. According to Minister of Energy, Green Technology and Water, Datuk Seri Peter Chin Fah Kui, he mentioned that the temperature in all government office should not be below 24 degree Celsius except for special places for example; hospitals which do required a low temperature level. The temperature was set as it is suitable for working environment and also to reduce the electricity bill of the government building (BERNAMA, 2011).

2.3 Earth Air Heat Exchanger (EAHE)

Earth Air Heat Exchanger (EAHE) is the mechanism by which air from outside is sucked in through ventilators to produce cool air in order to saved energy from electricity compare to what air conditioner do.

EAHE requires three main components which are air pump, pipes and an outlet. Air pump is used to suck in the air from the outside. The function of the pipe is to allow the air to go through it and outlet is where the cooled air comes out.

Figures above are few of the diagrams that explains EAHE system. EAHE system is very simple. First is to let the air from outside sucked into the inlet by using air pump. Pipes need to be buried under the ground and the air passed through the pipe comes out to the outlet. Thermal changes will happen under the ground. This happened when the heat from the air were transferred to the pipe and then to the soil particle. The soil particle would dissipate the heat and the temperature air comes out would be cooler compare to the temperature air comes in the pipe. After the air passes through the pipe, the air comes out from the outlet can be measures to determine whether there is thermal reduction happened or not. Figures below are few of the layout of EAHE system.

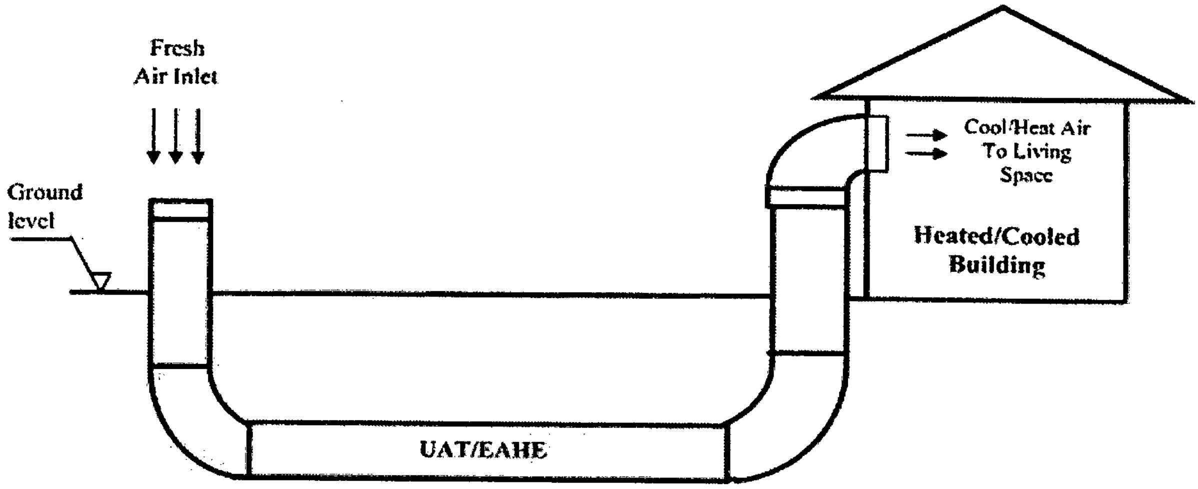

Figure 2.1 : Earth Air Heat Exchanger system. (Ozgener, 2011)

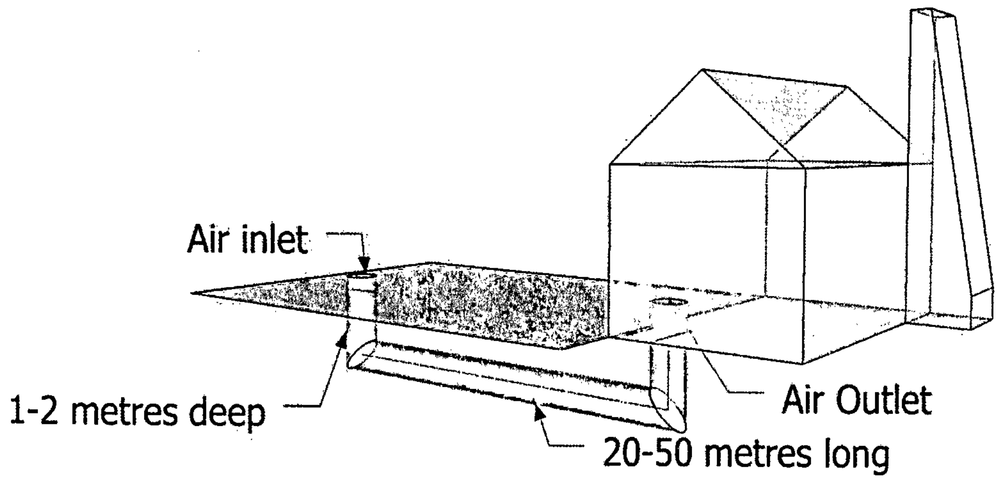

Figure 2.2 : Diagram of simple Earth Air Heat Exchanger system (Woodson *et al.*, 2012).

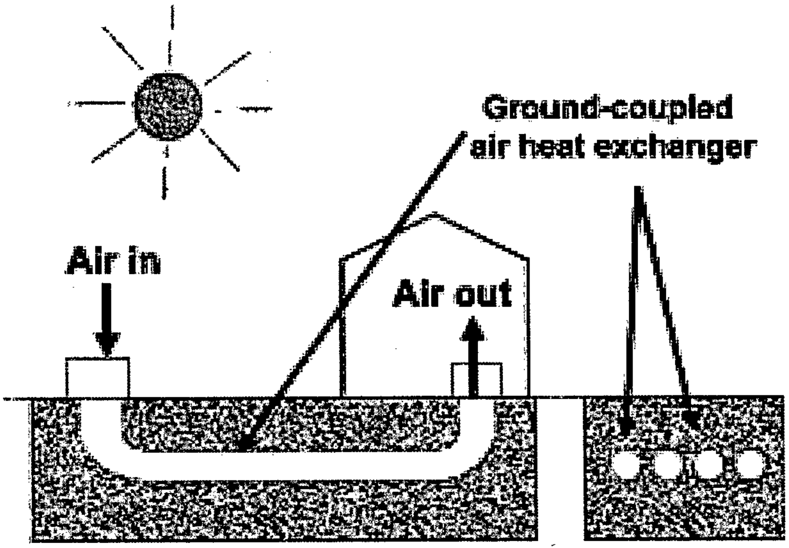

Figure 2.3 : Typical example of EAHE (Ojebode and Gidado, 2012)

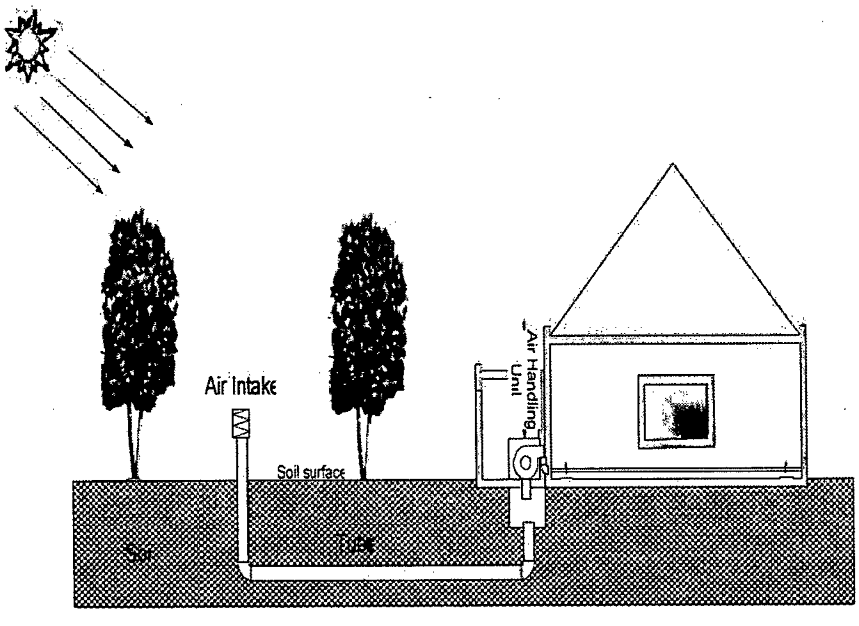

Figure 2.4 : Earth Air Heat Exchanger System (Ahmed *et al.*,2007)

Basically, this passive system was introduced to replace air conditioner. Both air conditioner and EAHE system function to cool the air inside a building.

Despite of both were used to reduce the temperature in a building, air conditioner and EAHE systems has few differences. Both also uses the electricity energy to cool the building but for air conditioner, the energy consumption is high compare to EAHE system. Air conditioner produced carbon dioxide which is harmful to the environment and lead to more global warming problem and also increased the surrounding temperature. EAHE system used the earth energy for cooling the air by heat transfer between the pipe and soil particle and it also helped to decrease the emission of carbon dioxide. So, EAHE system is more environmental friendly compare to the air conditioner.

As for maintenance, it is also one of the important matter which need to be considered. EAHE system has low operational and maintenance costs, saving of fossil fuels and related emissions (Ojebode and Gidado, 2012). Meanwhile, air conditioner needed high energy demand to operate and maintainting mechanical systems continously over long period of time during a day. Following is the summary of differences of using air conditioner and EAHE application.

Table 2.2 : Differences of using Air Conditioner and EAHE application.

DIFFERENCES	
Air Conditioner	**EAHE**
• Uses high electricity to operate	• Low electricity used to operate
• Producing CO_2 , harmful to environment.	• Did not produce CO_2 , environmental friendly.
• High maintenance	• Low maintenance
• High cost	• Low cost

2.3.1 Parameter affecting the thermal reduction.

The design of EAHE system depend on few factors which could affect the thermal reduction of the temperature. It includes ventilation airflow rates, pipe material, tube length and depth, velocity of the air crossing pipe and type of soil (Ascione *et al.,* 2010).In addition, Ahmed *et al.,*(2007) mentioned the magnitude of the heat exchange between air and pipe is dependent on factors such as soil temperature, air temperature, pipe dimension, air flow rate, pipe burial depth and soil pipe thermal properties that onclude density, heat capacity and thermal conductivity.

2.3.1.1 Cross section of the pipe.

According to De Paepe *et al.,*(2003) there are three dimension will affect the performance of the Earth Air Heat Exchanger which are include the pipe length, pipe diameter and also number of parallel pipe. Thermal performance and pressure drop both grow with length. Smaller pipe diameters give better thermal performance and also more pipe in parallel both lower pressure drop and rise thermal performance. Based on (Jílková, 2010) , it also stated when using the larger dimension than DN200mm (pipe dimension), a core of the current is created inside the pipe, which contributes only little to heat transfer. This means the smaller the pipe, the higher thermal reduction changes could happened. DN200 is type pipe with nominal bore of 8 inch with outside diameter 219.1mm.