Design & Analysis of Earth-Air Heat Exchanger for Room Heating & Cooling

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Abstract— The Earth Air Heat Exchanger (EAHE) is a promising technique which can effectively be used to reduce the heating and cooling load of a building by heating the air in winter and vice versa in summer. The main concern is to suggest ways for energy saving and minimise heating and cooling energy demands and carbon emissions in private residences. An EAHE utilizes the thermal mass of the soil surrounding or beneath the building in order to heat or cool incoming air. With the ground's large thermal capacity and relatively stable temperatures, outdoor temperature variations are dampened and ventilation heating and cooling loads are reduced. At a depth of 2-3 m under the surface of earth, temperature of soil remains constant at 22 ˚C for whole year. EAHE consists of buried tubes at this depth and atmospheric air is passed through this tube. During winter season the atmospheric air temperature is lower than 22˚C for most of the times of the day so heating of air will take place in the Earth Air Heat Exchanger and proper conditioned air will be obtained at the outlet of EAHE. Similarly in summer season the atmospheric air temperature is greater than 22 ˚C for most of the times and hence cool air will be obtained at the outlet of EAHE. To determine the best material for EAHE in order to get optimum results aluminium and copper tubes of same dimensions will be used. After performing experimentation results will be studied and the best material will be selected considering various parameters.

Key words: Earth Air Heat Exchanger, Heating, Cooling, Energy Saving

I. Introduction

Nowadays, the global increasing demand for energy and the decreasing of available conventional energy sources, allied with the environmental concerns, motivate the search for alternative and renewable sources of energy. In this context, the solar energy can be considered as one of the most important sources of energy and has several advantages over other sources. The solar energy harnessing has many application fields, e.g., residential and vehicular cooling, spatial and naval supply of energy. Advances in science have provided humanity knowledge that supports the development of appropriate technologies to improve the quality of life and to ensure the human beings survival on the planet. Energy is essential in this process and the domain of technologies provides the best ways to take advantage of different forms of energy available in nature. This search has been a challenge that accompanies the man along his existence. Following the offer, as well as, the political and economic world trend, the greatest amount of energy that mankind has been consuming lately comes from fossil fuels such as coal, oil and natural gas. The fossil fuels are considered non-renewable and cannot be returned for use at the same speed which they are being depleted. We must also consider the environmental impact of the extraction, transportation, storage and use of these products, principally represented by the risk of ecological disasters, the emission of polluting gases, highly harmful to the atmosphere, and the imbalance in the greenhouse effect. In a close time, therefore, fossil fuels will no longer be viable, either from an environmental standpoint, or even from the economic point of view. Given the importance of energy to the existence of our society, as we know, it is necessary to find alternative sources to replace conventional fuels or at least mitigate unbridled consumption and consequent impact on the environment. Solar radiation is a practically inexhaustible source of energy with huge potential for universal use and its harnessing and conversion into other forms of energy is possible. At sufficient depth of about 2-3 m from the ground surface, the ground temperature remains relatively constant. The ground temperature at this depth is warmer than air in winter and cooler than the air in summer. Such device is considered to be renewable energy source and it fulfils the energy demand for maintaining proper air conditioning. Using soil for heat dissipation is a traditional principle. Because of high soil thermal capacity, the temperature at sufficient depth under upper soil surface remains constant. Hence, the atmospheric air supplied through the pipe is either heated up or cooled down. The principle had already been known by ancient Persians and Greeks [1]. With an immense mass and insulating properties, relative to heat flux, the Earth's crust acts as a large reservoir for this inertial energy with alternating cycles of storage and supply of heat to the environment. As the depth increases, however, the amplitude of thermal variation decreases exponentially and phased out in time in comparison with the variation on the surface as a result of the thermal inertia of the soil. Thus, in cold periods, the basement does not seem as cold, and during warm periods the basement does not seem so hot, featuring a performance milder and more stable compared to the variation that occurs in the external environment. Therefore a strategy to make the indoor air temperature of a building remain more stable in comparison with external climatic variations is to circulate the outdoor air through buried ducts (Earth Air Heat Exchanger – EAHE), at depths technically and economically viable, aiming to promote the heat exchange between air and soil. Nowadays with rising energy costs and higher requirements of thermal comfort, the utilization of Earth Air Heat Exchanger is slowly coming back.

II. Objectives of Project

The objective of this work is to do a performance analysis of earth air heat exchanger using numerical modelling. The analysis would be done for cooling the air for the summer season. The associated objectives are as follows:

1) To define the geometrical layout of tubular heat exchanger which would be buried subsequently under earth for exchanging heat with the air.
2) To investigate the effect of various material and pipe layout on final temperature of air by constructing a prototype of the system.
3) To optimize the best material, layout and system to reduce the requirement of conventional energy source used for air conditioning.
4) To design an EAHE prototype system in terms of pipe diameter and length to obtain the output cooling capacity imposed by the experimental residential room's cooling load.
5) To analyse and evaluate the experimental heating and cooling performance of the EAHE prototype system.

III. EXPERIMENTAL APPARATUS & SETUP

A. Aluminium Tube

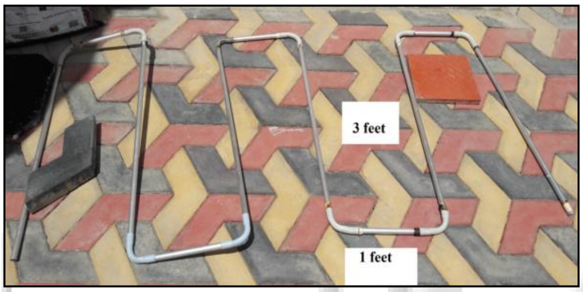

Fig. 1: Aluminium Tube (Horizontal Tubes)

Fig. 2: Aluminium Tube (Vertical Tubes)

An Aluminium tube is used as an Earth Air Heat Exchanger to take readings for Set 1 of experimentation. Thermal conductivity of Aluminium is 204.2W/mK and its Specific heat is 896 J/kgK .Diameter of Aluminium tube is 1.8 cm. The dimensions of Aluminium Heat exchanger tube are as shown in figure. Atmospheric air will be passed through one end of this tube by means of a blower and conditioned air will be obtained from other end. Both the ends of Earth Air Heat Exchanger made from Aluminium are connected by flexible rubber pipes. The outlet of EAHE tube is connected to Room by means of this flexible rubber pipes. Aluminium tube is buried underground at a depth of 3 metres (10 feet).

B. Copper Tube

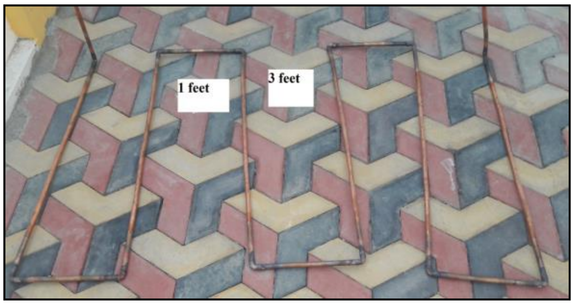

Fig. 3: Copper Tube (Horizontal Tubes)

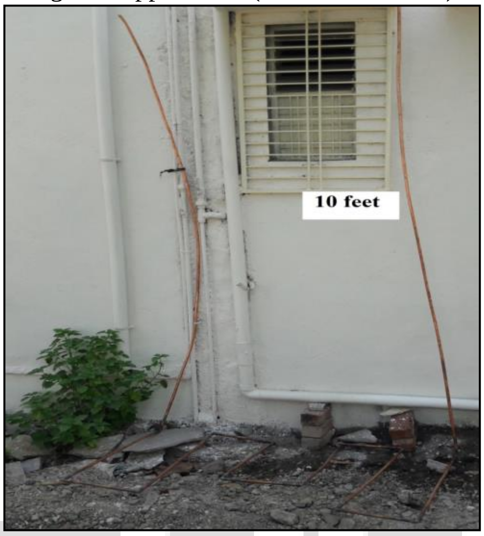

Fig. 4: Copper Tube (Vertical Tubes)

A Copper tube is used to perform experiment and note down readings for Set 2 of experimentation. Thermal conductivity of copper is 386 W/mK and its Specific heat is 383 J/kg K. Diameter of Copper tube is 1.8 cm. The dimensions of Copper tube are as shown in figure. Atmospheric air will be passed through one end of this tube by means of a blower and conditioned air will be obtained from other end. Both the ends of Earth Air Heat Exchanger made from Copper are connected by flexible rubber pipes. The outlet of this EAHE tube is connected to Room by means of flexible rubber pipe. Copper tube is buried underground at a depth of 3 metres (10 feet).

C. Pit

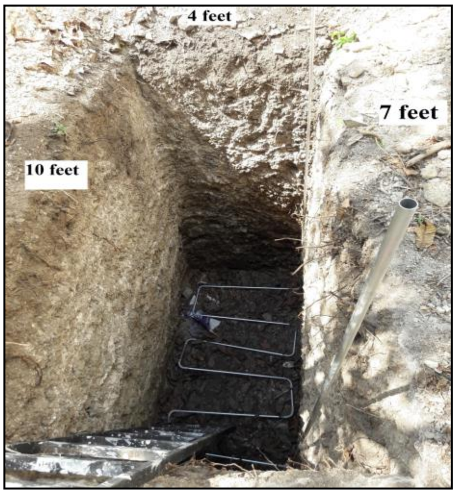

Fig. 5: Pit (Bore) for Aluminium EAHE

Two pits (bore) are dug of size 4×7×10 feet (w×l×d).The sand that was present in most part was limestone. The Pit (bore) will act as a heat source or sink for air flowing through EAHE tubes buried underground. During winter season when the required air is hot at that time earth will act as a heat source. Conversely, during summer season, when the required air is cold at that time earth will act as a heat sink and cold air will be supplied at EAHE outlet. The temperature of earth at a depth of 2-3 m remains constant throughout the year at 20˚C.

Fig. 6: Pit (Bore) for Copper EAHE

D. Blower


Fig. 7:

The blower is a device which is used to supply air at a high velocity. The blower used in the experimentation is a hand operated air blower Atmospheric air enters inside the blower axially and air is discharged from the blower radially at high velocity. The velocity of air can be controlled as per requirement. The velocity of air can be increased or decreased by rotating a regulator attached to it. Blower has a motor of 24 volts and blower consumes power equal to 60W. The outlet of blower is attached to the inlet of EAHE by using Flexible rubber pipes.

E. Flexible Rubber Pipes


Fig. 8: Flexible Rubber Pipes

Flexible Rubber pipes are connected to both the ends of EAHE tube. At inlet rubber pipe is connected to supply atmospheric air through EAHE tube. The conditioned air coming out from outlet of EAHE is passed inside the room through Rubber pipe. Rubber pipe are flexible and they do not require elbows or bends to fix their end at the required point. Hence, losses occurring inside the pipe because of flow are very less. Rubber pipes used in the experimentation are of 1.9 cm diameter

F. Thermometer

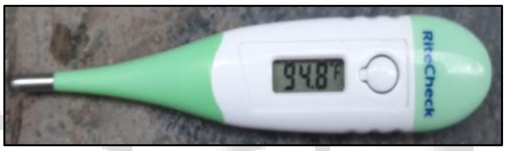

Fig. 9:

A thermometer is a device that measures temperature or a temperature gradient. A thermometer has two important elements: (1) a temperature sensor (e.g. the bulb of a mercury-in-glass thermometer) in which some physical change occurs with temperature, and (2) some means of converting this physical change into a numerical value (e.g. the screen on a thermometer). Thermometers are widely used in industry to control and regulate processes. The Thermometer will be used to measure the temperature of air coming out from EAHE which is supplied inside the room.

G. Anemometer

Fig. 10: Anemometer

An Anemometer is a device used for measuring the velocity of wind and is also a common weather station instrument. It is used to measure the velocity of air coming out from Earth Air Heat Exchanger. The ideal velocity of air for its proper distribution should be 1m/s to 2.5 m/s.

IV. EXPERIMENT PREPARATION & PROCEDURE

Fig. 11: Working Model of Aluminium EAHE

Fig. 12: Working Model of Copper EAHE

Figure shows the general overall set up for experiments with the testing apparatus. The Earth Air Heat Exchanger gives air at higher temperature at night than day time during winter season. On the contrary it gives lower temperature air at day time than night time during summer season. But this does not means that it cannot be used during other time of the day. It can be used, but the results obtained will not be optimum. It can be used along with other room conditioning devices. This will ultimately reduce power consumption of air conditioning devices.

V. RESULT & DISCUSSION

The below graphs are plotted by using outlet temperature of Aluminium and Copper EAHE as well as inlet temperature of air which is same for both of them. These readings were noted for different timings in a single day. This graphs shows the variation of outlet temperature of air from both the EAHE for comparative study. These graphs are plotted by using readings of winter season (Dec-Jan).

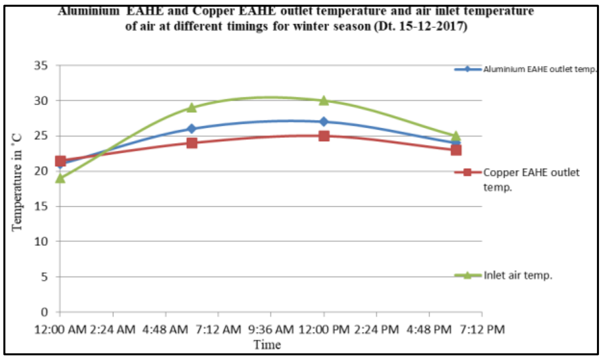

Fig. 13: Temperature of Air (˚C) Vs. Time

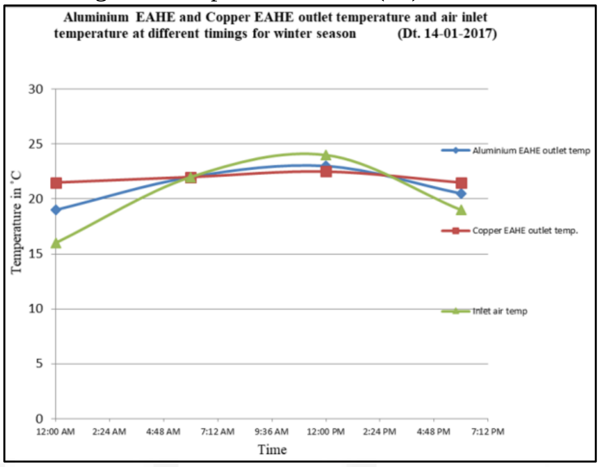

Fig. 14: Temperature of Air (˚C) Vs. Time

The below graphs are plotted by using outlet temperature of Aluminium and copper EAHE as well as inlet temperature of air which is same for both of them. These readings were noted for different timings in a single day. This graphs shows the variation of outlet temperature of air from both the EAHE for comparative study. These graphs are plotted by using readings of summer season (March-April).

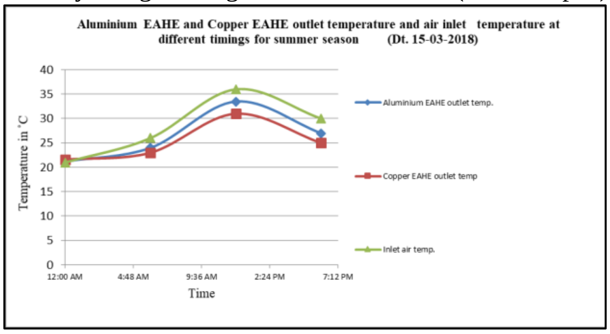

Fig. 15: Temperature of Air (˚C) vs. Time

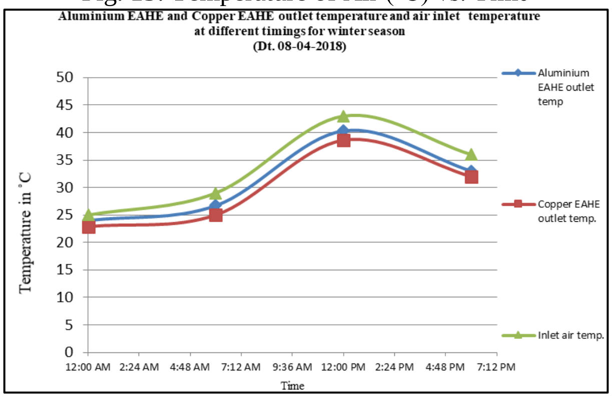

Fig. 16: Temperature of Air (˚C) vs. Time

VI. Conclusion

The Earth Air Heat Exchanger (EAHE) used in this project for experimentation was designed in a best way so as to get maximum amount of heat transfer in the specified pit (bore) volume buried in the earth.

The Earth Air Heat Exchanger was made using two materials namely Aluminium and Copper. As the temperature of earth at a depth of 3 m is 22˚C. So the air passing through the EAHE should be less than 22˚C at inlet for winter season. Otherwise air will get cooled if its temperature is more than 22˚C.Because heat flows from hot body to cold body. If the inlet air temperature increases then there is no need to use EAHE. Similarly, during summer season the inlet air should have temperature more than 22˚C for getting cold air at outside. In India both winter and summer lasts for 3-4 months and are equally intense so on an average EAHE can be used in our country at least for twelve hours in both the season. Because in winter the atmospheric air temperature after sunset to sunrise remains lower than 22˚C. During summer the atmospheric air temperature remains greater than 22˚C for more than twelve hours. For remaining time an air conditioning unit will be used to supply conditioned air. It will consume less power as it will work for less time.

Thus, the data obtained after studying literature and carrying out experimentation carefully the results obtained after using Aluminium and Copper EAHE implies to use Copper as the material for EAHE.

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