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Review of Earth Tube Heat Exchanger

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ABSTRACT

Earth-air heat exchangers, also called ground tube heat exchangers, are an interesting technique to reduce energy consumption in a building.They can cool or heat the ventilation air, using cold or heat accumulated in the soil. Several papers have been published in which a design method is described. Most of them are based on a discretisation of the one-dimensional heat transfer problem in the tube. Three-dimensional complex models, solving conduction and moisture transport in the soil are also found. These methods are of high complexity and often not ready for use by designers. The temperature of earth at a certain depth about 2 to 3m the temperature of ground remains nearly constant throughout the year. This constant temperature is called the undisturbed temperature of earth which remains higher than the outside temperature in winter and lower than the outside temperature in summer. When ambient air is drawn through buried pipes, the air is cooled in summer and heated in winter, before it is used for ventilation. The earth air heat exchanger can fulfill in both purpose heating in winter and cooling in summer.
Keywords : Earth Tube Heat Exchanger, Renewable Energy, Ventilation

I. INTRODUCTION

The Energy consumption of buildings for heating and cooling purpose has significantly increased during the decades. Energy saving are of major concern everywhere is a particular challenge in desert climates. We have been developing earth-tube heat exchanger (ETHE) for use in greenhouse in arid areas like Kutch.

Figure-1: *Fully Furnished Greenhouse, Kothara-Kutch Showing Blower and Suction Duct*

Figure-2: *Tomato being picked from Greenhouse*

The heat exchangers, which are receiving much attention in recent years. These simple heat exchangers are made up of a single tube (or multiple in parallel) through which a fluid is circulated. By placing the tube sufficiently deep (more than 1 m below the surface for a moderate climate zone such as Belgium), the fluid which is circulated can be cooled down in summer and heated up in winter. This is due to temperature lag which occurs between the surface and more profound soil layers. The Intergovernmental Panel on Climate Change (IPCC) (Pachauri and Reisinge 2007) estimates that the Earth's surface temperature has increased by 0.6°C and that human activities, such as burning fossil fuels for energy, have played a major role in climate change. Unfortunately, the world's insatiable thirst for energy will only increase as poorer countries become more industrialized. In several European countries this technique is imple-mented in private houses and office buildings. Recent examples are found in Germany and Switzerland Architects and building installation designers are often interested in installing earth-air heat exchangers, but due to lack of knowledge or design criteria, the introduction of the heat exchanger in the building design is omitted. Earth tube heat exchanger (ETHE) is a device that enables transfer of heat from ambient air to deeper layers of soil and vice versa [14]. Since the early explanation of its use in cooling commercial buildings, there has been a considerable increase in its application [12]. For many years earth heat exchangers have been acknowledged to be useful tools for the acclimatization of buildings, both to decrease energy consumption and increase building comfort [5], [8] revealed that only a moderate climate having a large temperature difference between summer and winter is suited for earth tube heat exchangers. Different configurations of earth –to-air heat exchanger have been used in Central and Western Europe as heat suppliers during the cold season [16]. Their performance depends on the air flow rate, convective heat transfer at the tube surface, depth, dimensions and number of pipes and soil properties [6]. Since the soil transports heat slowly and have a high heat storage capacity, its temperature changes slowly depending on the depth of measurement [1].

II. METHODS AND MATERIAL

A. Experiment Setup

The experimental setup is an open loop flow system has been designed and fabricated to conduct experimental investigation on the temperature difference for inlet and Outlet section, heat transfer, and coefficient of performance and fluid flow characteristics of a pipe in parallel connection.

Figure-3: *ETHE before being covered*

The experimental data are to be used to find the increase of cooling rate for the summer (May 2014) condition, and heating rate of winter (November 2014) condition heat transfer coefficient. There are five temperature sensors located inside the pipe: 5 m, 10 m, 15 m, 20 m and 25 m away from the air inlet. In addition, there are temperature sensors buried 0.5 m, 1.0 m and 1.5 m in the ground to measure the soil temperature gradient. To clean the EAHX, a nylon cord was placed inside the tubes, which allows a cloth to be pulled through the system, removing all of the dust and debris.The experiment room and the control room are each 3.50 m × 2.75 m × 5.35m. The experiment and control rooms share a wall, and both of the rooms are connected to a larger laboratory. The walls are 18 cm thick and made from locally produced brick covered in concrete. The ceiling is made from wood slates, and the roof of the structure is corrugated steel. This is a typical construction for homes and offices in Burkina Faso. The ventilator used to draw the air through the pipes is 14 W and has a volume flow rate of 95 m3/hr.

B. Advantage and Disadvantage

Being result of a natural phenomenon deep ground as source and sink is available easily in most places in the world. Such a use is sustainable and equivalent to having a renewable energy source. ETHE based systems cause no toxic emission and therefore, are not detrimental to environment. Ground Source Heat Pumps (GSHPs) do use some refrigerant but much less than the conventional systems. ETHE based systems for cooling does not need water - a feature valuable in arid areas like Kutch. It is this feature that motivated our work on ETHE development. ETHEs have long life and require only low maintenance. However, initial installation costs are likely to be higher than the comparable conventional (refrigerant based) systems. Conventional systems can be customized easily for varied applications and industry is well developed. This is not yet the case for ground coupled systems.

C. Performance of Large Diameter Earth-Air Heat Exchangers

Tjelflaat [4] collected data on a 1.5 × 2 × 13.5 m (w × h × l) EAHE serving an addition to the Media School in Grong, Norway, about 200 km north of Trondheim, which has a mean annual temperature of 5.0 °C [5]. The “hybrid” system design was intended to heavily exploit wind and stack forces to drive air flow, supplemented by a supply fan and an exhaust fan controlled by the building management system. Tjelflaat’s analysis focused on cooling performance, but Jeong [6] and Wachenfeldt [7] used the data to support validation of a simulation model of the system. One of Jeong’s simulations in [6] indicated that the EAHE raised the supply air temperature by as much as 12 °C (from −7 °C to 5 °C). However, the simulation seemed to result in a supply air (duct discharge) temperature equal to the duct surface temperatures, which were set to a constant 6.1 °C duct wall boundary condition. The duct wall temperatures used by Jeong differed from measured conditions (discussed below). This will be discussed below following the two paragraphs immediately below that address Wachenfeldt’s research. Jeong provided few details to explain this. In a second simulation of both building thermal performance and airflow, Jeong [6] reported that the EAHE raised supply air temperature by as much as 11 °C (from −7 °C to 4 °C). Although the temperature rise from the two simulations was similar, the second simulation produced a supply air temperature profile that fluctuated with the inlet air temperature. Overall, Jeong focused on the whole building simulation. Wachenfeldt [7] simulated the performance of the addition to the Media School, using data collected by [4], focusing on the simulation of the EAHE air flows. As with [4], the analysis primarily addressed cooling performance. Wachenfeldt highlighted the difficulty of predicting energy performance of natural (wind- and buoyancy-driven) ventilation systems, because of variations in airflow paths and rates, sensitive to both internal parameters and the outdoor environment. He noted the importance of fans in enhancing convective heat transfer between air and duct walls.

III. RESULT AND DISCUSSION

Different soil types have a different penetration depth, related to their physical properties. For example, clay soils tend to have a smaller penetration depth, about 0.12 m, due to their higher water content. Changing the penetration depth from 0.17 to 0.12 m only shows a small effect. The same was found for the tube wall conductivity. Increasing the tube wall conductivity decreases the conductive heat transfer resistance through the tube wall. However, because the tube only has a small to negligible contribution to the total resistance (see Fig. 3) the effect is very small. The soil conductivity has a stronger impact, which is illustrated in Fig. 7. Note that the selected value of 0.3 W/m-K is an extreme condition, usually soil thermal conductivity varies around 1 - 1.5 W/m-K. Yet it is clear that for high air flow rates, the soil conductivity contributes significantly.

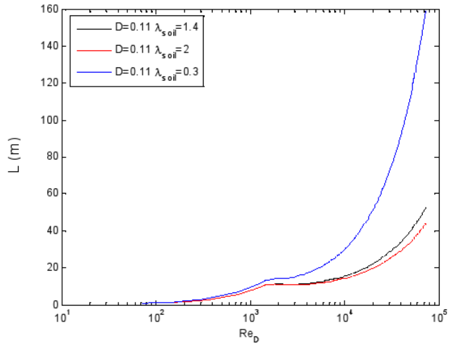

Figure 5: *Required tube length L to reach ε = 0.8 for varying soil thermal conductivity and air flow rate.*

During this time period, the outside temperature and the ground temperature were recorded approximately every three hours, and the RMSE between the theoretical and measure values ranged from 0.02°C to 0.10°C. Figure 4 is a plot of the theoretical and measured temperatures during the 52-hour period. In the figure, the origin on the x-axis represents midnight on 12 May. The data clearly show the soil temperature decreasing with depth and the phase shift of the ground temperature with respect to the outside air temperature. At the hottest time of the day (11:45 to 15:00), the ground temperature was the coolest, and at the coldest time of the day (06:00 to 07:30), the ground temperature was the hottest.

IV. CONCLUSION

Analytical models were developed for an EAHE and an EWHE combined with a compact water-air heat exchanger. The results show that for both types of heat exchangers, at higher flow rates the thermal resistance of the soil becomes dominant, in particular for the EWHE.

This should always be considered in the design process. The CHE effectiveness must be as high as possible. A parameter study of louvered fin units was undertaken to obtain a value of at least 0.8. There is a strong interaction between the two heat exchangers in the EWHE case: when varying the flow rate their effectiveness show an opposite trend. On the whole the required tube installation length is larger for the EWHE compared to an EAHE, but the tubes are much smaller. A few case studies using two CHE in parallel showed further improvement of the EWHE.

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