Numerical and Experimental Analysis of Earth Air Tunnel Heat Exchanger: A Review

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***Abstract* —The heat exchanger is device that used for transfer of internal thermal energy between two or more fluids at different temperatures. This study gives an analysis of ground coupled heat exchangers used to improve the efficiency of heating, ventilation, and air conditioning systems. A ground coupled heat exchanger can be used in either a heating or cooling mode by taking advantage of a "near constant" ground temperature. The "near constant" ground temperature (around 4m) can be used as either a heat sink to remove heat to cool a building, or as a heat source to heat a building. The purpose of this paper is to increase the awareness of the different assumptions and methodologies between these calculation methods. The main objective of this work is to understand the behavior of fluid in heat exchanger. This paper reviews on performance enhancement of earth air tube heat exchanger with different atmospheric conditions.**

***IndexTerms*—Earth tube heat exchanger, Earth Undisturbed temperature, Geo thermal heat exchanger.**

I. INTRODUCTION

Factors like rising electricity prices and the environmental factors have forced us to look for cheaper and cleaner alternatives to various applications. Water or air heating and cooling is one such device that heavily consumes electricity and its emissions are detrimental to the environment. The gap in the demand and supply of the electricity in our country limits the suitability of the water heating and cooling. One of the alternatives that can address the above mentioned concerns and the most promising energy resources available for us is geothermal energy. It is a form of clean energy because using it doesn't emit any type of pollutions, and renewable energy because the heat within the ground goes around in a cycle so we are assured that there will always be heat available to us. Geo thermal heat exchangers are the underground heat exchanger that can capture heat from and/or dissipate heat to the ground. They use earths near constant ground temperature to warm or cold air or other fluids for agriculture, residential and industrial uses. A ground coupled heat exchanger can be used in either a heating or cooling mode, depending on the climate and season. There are many different configurations that can be used to make a ground coupled heat exchanger system. These systems can use open and closed loops, different fluids, or any combination in the system all to optimize ground coupled heat exchangers.

The design parameters that impact the performance of the Earth Coupled Heat Exchanger are:Tube Depth, Tube Length, Tube Diameter, Air Velocity, Air Flow rate, Tube Material, Tube Arrangement.

There are four different types according to layout of pipe in the ground.

1. Horizontal/ straight Loop
2. Vertical Looped
3. Slinky/ spiral Looped
4. Pond/Helical Looped

Soil temperature at the depth of below 4 meter fairly constant throughout the year and it is equal to average annual ambient air temperature.

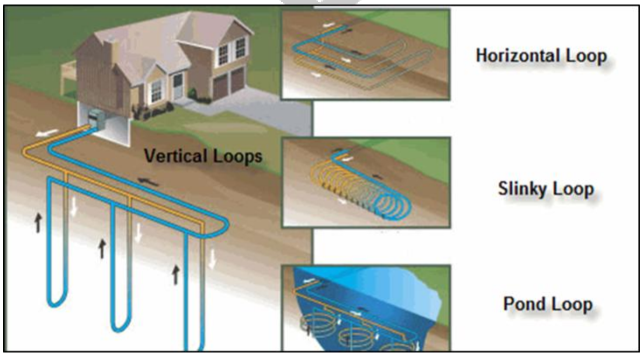

Figure 1: Ground Coupled Heat Exchanger Loops [15]

Advantages of Geothermal Heat Exchangers: High efficiency, lower energy consumption, lower energy cost, low maintenance cost, Reduced maintenance costs, Modular, residential-sized units, no complicated controls required, no outdoor equipment, quiet operation, greater occupant comfort, low source energy use and low air pollutant emissions – green technology, reduced mechanical room space.

Disadvantages of Geothermal Heat Exchangers: First cost can be higher than for conventional systems, not all system types feasible in all locations, limited pool of designers, plant construction can adversely affect land stability.

II. LITERATURE REVIEW

AriffinMohd et al. [1] investigated the most appropriate pipe materials that will predict the optimum air temperature reduction through computer simulation studies for achieving thermal comfort. The study utilizes the Energy Plus environmental simulation program to investigate the performances of three pipe materials system: single pipe material, hybrid pipes and insulated hybrid pipes system. After the study they found that the insulated hybrid pipes system gives the best temperature reduction indicating reasonable cooling and energy savings potentials.

Bansal et al. [2] carried out the experiment on the pipe of 23.42m length and 0.15m diameter, temperature down to 4.1–4.8 °C has been observed for the velocity limits from 2 to 5m/s. They observed the hourly heat gain through the system is found to be in the range of 423.36–846.72kWh.

Bisonia et al. [3] [5] evaluate the cooling and heating potential of Earth Air Heat exchanger for summer and winter season for the system developed in Bhopal. The experimental set up of earth air heat exchanger system with PVC pipe of 19.228m length and 0.1016m diameter buried at 2m depth. The system is simulated in computational fluid dynamics platform. The simulation and experimental result are obtained for air velocities of 2, 3.5 and 5 m/s. In summer cooling the drop in air temperature obtained from experimental set up of heat exchanger varies from 12.9 °C to 11.3 °C, and for winter heating the maximum and minimum temperature is 8.2 °C and 6.8 °C. Diameter of pipe and air velocity was found to greatly affect the thermal performance of Earth Air Heat exchanger.

Bisoniya et al. [4] carried out a study to evaluate the annual thermal performance of the EAHE system for hot and dry climatic conditions of Bhopal (Central India). A 3D model based on computational fluid dynamics (CFD) was developed with specified dimensions (length of buried pipe 19.228 m, diameter of pipe 0.1016 m, and depth of burial 2 m) to evaluate the heating and cooling potential of the EAHE system, with airflow velocities of 2, 3.5, and 5 m/s. The simulation results were validated against experimental observations from an experimental setup installed in Bhopal.

G.N. Tiwari et al. [6] in the present work the ground temperature have been validated for climatic condition of Sriperumbudur near Chennai, India to evaluate thermal conductivity and diffusivity of the soil. For the evaluated thermal conductivity of the soil, an EAHE has been designed for a given dimension of room with optimized values of number of air changes, length of pipe, radius of pipe and depth at which heat exchanger to be installed below the surface of the earth. It has been observed that there is a decrease of 5 – 6°C in the outlet air temperature in summer for a number of 5 air changes with 0.10 m and 21 m optimized diameter and length of pipe respectively.

JakharSanjeev et al. [7] worked on thermal performance of earth air tunnel heat exchanger (EATHE) coupled with a solar air heating duct experimentally. To enhance the heating capacity of system by coupling it with a solar air heating duct at the exit end. Results show that the air which comes out of coupled EATHE system is relatively hotter than the air supplied by the stand alone EATHE system. It was found that the heating capacity of EATHE system got increased by 1217.625–1280.753 kWh when it was coupled with solar air heating duct with a substantial increase in room temperature by 1.1–3.5 ◦C.

OnderOzgener et al. [8] in this paper Transient heat flow principles were used with assumptions of one dimensional heat flow, homogeneous soil, and constant thermal diffusivity. The thermal behavior of the ground (near the surface)as a function of depth and time is difficult to simulate from one point since there are many parameters such as short term weather variations, seasonal variations, moisture content of soil, and thermal conductivity of soil etc. affecting on the temperature of ground. The paper aims at improving a model predicting daily soil temperatures depending on depth and time.

OnderOzgener and LeylaOzgener [9] have investigated the performance characteristics of an Earth Air Heat Exchanger for agriculture building heating in Turkey. They have design setup with the length of 47m, 56 cm nominal diameter with u bend horizontal and galvanized earth heat exchanger at 3m depth. The minimum and maximum value of coefficient of performance (COP) is 0.98 and 6.42 respectively. The total average COP in heating season is obtained as 5.16.

R.Ralegaonkar et al. [10] have designed the Geothermal cooling system for composite climate zone like Nagpur, Maharashtra, India .They do the complete design of geothermal cooling system for particular case study with finding essential data like earth mean temperature, total heat transfer, heat transfer coefficient and length required for the system and others. They have also compared the conventional cooling system and geothermal cooling system and conclude that geothermal system saves energy and reduce the carbon emission.

Sharan and Jadhav [11] have conducted experiment on single pass earth tube heat exchanger. They conducted experiment in Ahmadabad Gujarat (2000) India these found. If A single pass earth-tube heat exchanger (ETHE) was installed and ETHE is made of 50 m long MS pipe of 10 cm nominal diameter and 3 mm wall thickness. ETHE is buried 3 m deep below face. Air rate in the tube is 11 m/sec. Air temperature is measured at the inlet of the pipe, in the middle (25 m), and at the outlet (50 m), by thermistors placed within the pipe. The result concludes that: In cooling mode mean to 3.3. Cooling test was of 7 hour nonstop duration during the day. In heating mode it mean to 3.8. Heating test was of 14 hour constant duration through the night.

Sharan and Jadhav [12] conducted an experimental study in Ahmedabad for determining the efficiency of Earth Air Heat Exchanger to cool the air in summer and warm it up in winter. For this, a pilot test was carried out for a 50-m long; 10-cm diameter mild steel pipe with wall thickness of 3 mm, placed at a depth of 3 m. The air was moved at 11 m/s through the pipe. It was observed that Earth Air Tube Heat Exchanger caused a drop of around 12 °C in the summer months and an appreciable rise in the winter months in the circulated air.

Vibhute et al. [13] have done research on conventional air conditioner and geothermal air condition by evaluating the energy efficiency ratio (EER) and tonnage (TR) and presented the comparison among them for different outside temperature and found that geothermal heat pump use 25% - 50% less electricity than conventional heating or cooling systems, and found that Geothermal

Heat Pump is better than conventional air conditioning. Also observed that geothermal have relatively few moving parts, and because those parts are inside a building they are durable and highly reliable.

III. Summary of Literature Review

Numerical and analytical observations generate a number of research gaps from the literature review exercise conducted in this chapter. The analysis thus provides some research gaps. Followings are some fundamental issues that published literature does not discussed significantly.

1. Literature review suggest that most of work on geothermal exchanger done on straight tube channels so there is wide scope of using spiral or helical tube heat exchangers and other tube arrangement.
2. The heat exchanger tube material and cross section can also give significant result.

IV. Result and conclusion

From the above literature review work some of the remarkable point has been noticed. The decrease in temperature is sharp for the first some length of pipe and then it became moderate afterwards. As the air flow velocity increases that also increase the outlet temperature. The results also show that conduction plays very important role in the cooling of air, it is evident from the fact that temperature remains constant where the insulation is done.Tube length is independent parameter influence to pressure drop. Diameter and velocity have combined influence on pressure drop. For the same diameter increasing velocity will gives the increasing pressure drop.At higher outlet velocity and maximum temperature difference, the system is most efficient to be used.

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