Review on Earth Air Tube Heat Exchanger

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Abstract - The demands of cooling energy & thermal comfort requirements are rapidly increasing day by day due to the global warming effect. The temperature of Tropical and Subtropical regions is as high as 50 °C in summer, and it is as low as below 10 °C in winter. So we may utilize the fact that the temperature of the earth at a depth of 2–3 m is constant throughout the year irrespective of the season, and that constant temperature is called earth undistributed temperature (EUT) so this may be utilized for heat rejection of air in the summer for cooling purpose (heat source) and heat addition of air in the winter for the heating purpose. The current setup is developed to explore the possibility of EATHE installation for heating and cooling in this region to curb the demand for energy Consumption. In the present experiment, a setup is established. It consists of PVC/Copper pipes and a blower. To analyze the performance of EATHE of the current setup, measurement of atmospheric temperature and inside temperature of soil at a depth of 6 feet in summer is done. Calculations of the amount of heat transfer and work input to the blower were done by applying suitable thermodynamic formulae and data. Calculation of the coefficient of performance was also done.

Key Words: **Earth-air heat exchanger, Ambient air, Buried pipes, geothermal, exchanger.**

1.INTRODUCTION

With increase in demand of thermal comfort and cooling the use of electricity and energy are increasing day by day. Due to the limited sources of energy, it is necessary to find out the alternate source of to preserve the conventional fuels and to save the energy of earth. The best alternatives are adopting passive design strategies The earth air heat exchangers are considered as an effective replacement for heating or cooling of buildings. Worldwide, it is estimated that the residential buildings, offices, and stores consume around 40% of our energy and 70% of our electricity. Heating and cooling for residential, commercial, And industrial purposes account for a large share of total final energy demand. To lessen the burden on the active systems transforming renewable energy into the thermal or electrical energy, a necessary first step is to apply the optimal combination of passive design strategies, foremost among them passive solar design strategies. Geothermal energy is considered a renewable source of energy (never-ending source of energy). Traditional heating and cooling system required compressor, condenser, and evaporator setup. While Earth tube heat exchanger is an underground heat exchanger that can capture heat from the ground for heating purposes and dissipate heat to the ground for cooling purposes. Earth tube heat exchanger is a creative way to use the geothermal energy to our advantage, both for heating and cooling inside the living area. Earth tube heat exchanger required blower to move the air throughout the setup of the ground loop heat exchanger. Heat is extracted from or rejected to the ground through a buried pipe, through fluid flow. This simple setup helps in reducing cost, electricity consumption for the system. This system eliminates the compressor, condenser, and evaporator cost by simply using geothermal energy.

There are two major types of earth tube heat exchanger system.

1)OPEN-TYPE EARTH TUBE HEAT EXCHANGER

In the open-type earth tube heat exchanger system, the air from the atmosphere passes through tubes that are buried in the ground where the heat transfer between the air and the tube takes place due to temperature differences.

2) Closed-type earth tube heat exchanger

In the closed-type earth air heat exchanger system, the air from the room passes through tubes that are buried in the ground where the heat transfer between the air and the tube takes place due to temperature differences.

EATHE EFFECTS OF VARIOUS PARAMETERS

1) Material Effect*:* In the beginning, EATHE was built using steel pipes, but after that, numerous kinds of materials were experimented with. According to research, PVC materials have the same impact. Because of this, PVC may be used in place of more expensive materials, and the product will last longer. A slight difference in air temperature at the pipe outlet between copper and PVC may be attributed to the better conductivity of copper

2) Effect of Velocity of Air inside Pipe: Researchers tested the impact and found that increasing the air velocity from 2.0 to 5.0 decreased the temperature of the air exiting the tube. Air contact with the ground is diminished 2.5 times, while the convective intensity move coefficient ascends by 2.3 times. To put it another way, the higher the wind speed, the smaller the temperature increases are since the latter impact is more dominating. At high speeds, the reduced contact time results in poor performance.

3) Tube Length's Effect*:* We can conclude that some length is important and no performance improvement is seen beyond a certain length, regardless of length. From this, we can conclude that a length of about 10 m is insufficient for all considered climatic zones, according to Lee KH, Strand RK, but the length is If it exceeds 70m, there is no big advantage.

4) Effect of Tube Depth*:* Outdoor conditions and soil composition, as well as their thermal and water content, influence the temperature of the soil. The temperature of the ocean floor varies, but it eventually becomes stable. This is the same year-round temperature. Since this temperature stabilizes after a depth of 1.5 meters, it can be concluded that the depth should be higher. According to depths greater than 3.5 meters are not allowed.

5) Tube Length, Diameter, and Air Flow Rate Impact*:* The cooling capacity of a system is directly proportional to the overall area, which is the foundation of the design. Changing the pipe's length or diameter has two effects on this. The mass flow rate decreases as the diameter is increased, but the pressure drops and fan output rises as the length is extended. EPEC 2002 recommends that parallel pipes of appropriate length and diameter be used. The air reaches the ground temperature quickly, so no large pipes are needed. Generally, 150-450 mm pipes are used.

A) DESIGN PARAMETERS

1. Pipe Length: Increasing the pipe length allows for greater heat exchange between the air and the soil, resulting in more significant temperature conditioning. There's a point of diminishing returns however, as excessively long pipes contribute to higher pressure drops and fan energy requirements.

2. Pipe Diameter: Pipe diameter plays a role in balancing friction losses and heat transfer. Wider pipes provide less resistance to airflow but offer less surface area for heat exchange. Conversely, narrower pipes create more friction and require stronger fans, but they promote better heat transfer due to increased surface area.

3. Burial Depth: The ground temperature remains more stable with increasing depth. Shallower depths can be advantageous in heating applications as they capture warmer ground temperatures, while deeper trenches are more suitable for cooling as they access cooler subsurface soil.

4. Airflow Rate: The rate of airflow through the pipes determines how much air gets conditioned and how quickly. Higher airflow rates lead to greater temperature changes but also require more powerful fans, impacting system energy consumption.

5. Soil Type: Different soil types have varying thermal conductivities. Sandy soils tend to have lower thermal conductivity compared to moist clays. So denser, moister soils generally perform better for EATHE systems.

6. Pipe Material: The material of the pipes influences heat transfer efficiency. Copper offers superior thermal conductivity but comes at a higher cost. PVC is a more budget-friendly option with decent thermal properties, but might not be ideal for applications demanding maximum efficiency.

1. Copper has a thermal conductivity of 385 W/mk.

2. Aluminum has a thermal conductivity of 205 W/mk.

3. Brass has a thermal conductivity of 109 W/mk.

4. Iron has a thermal conductivity of 79.5W/mk.

5. Steel has a thermal conductivity of 50.2 W/mk.

6. PVC has a thermal conductivity of 0.19 W/mk.

We take Copper and PVC pipes as tube material for our analysis.

METHODOLOGY AND SIMULATION

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. The experimental data are to be used to find the increase of cooling rate for the summer condition, and heating rate of winter condition heat transfer coefficient the cool air for required place in summer climate and hot air required place in winter.

Assumptions:

• The surface temperature of the ground is defined as equal to the ambient air temperature, which equals the inlet air temperature.

• The PVC pipe used in the EAHE is of uniform cross section.

• The thickness of the pipe used in the EAHE is very small; hence, thermal resistance of pipe material is negligible.

• The temperature on the surface of the pipe is uniform in the axial direction

3-D MODELS DESIGN

The design of ETHE is considered on the basis of uses, for commercial buildings as well as individual residential houses of small area. This is the very compact design of ETHE, which can be easily setup in small area land. The whole design of ETHE is designed on the solidwork software with more precision and accuracy and exported to simscale for further analysis. There are many advantages of this compact design, such as:

- It can be setup in small land area due to its compact design.
- Its setup labour's cost will minimum, most probably in those residential buildings with basement. It must be setup in initial stage of construction.
- It can be setup in non- commercial houses.
- Low maintenance charge due to its tube material which is aluminium

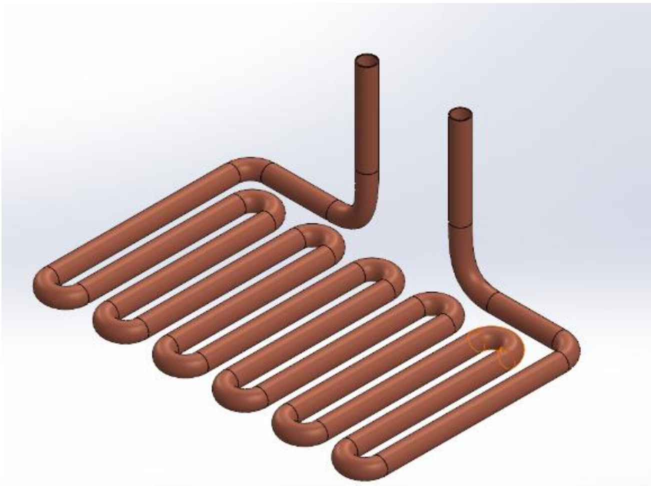

Figure 1. Shows 3-d model of copper tube

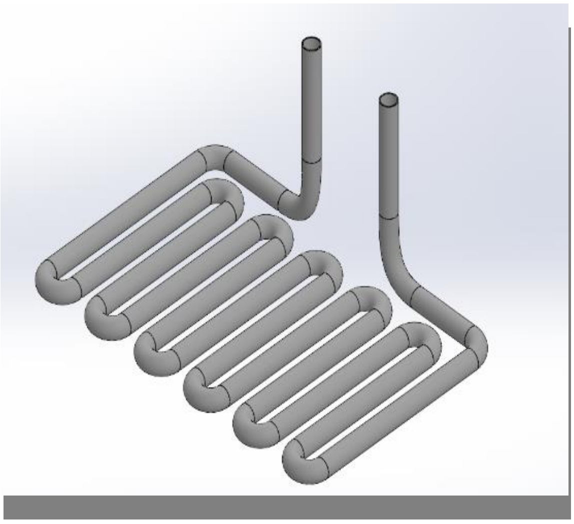

Figure 2. Shows 3-d model of PVC pipe

DESCRIPTION OF CFD MODEL

Computational fluid dynamic (CFD), well known as a powerful method to study heat and mass transfer for many years. CFD codes are structured around the numerical algorithms that can tackle fluid flow problems. It provides numerical solutions of partial differential equations governing airflow and heat transfer in a discretised form. Complicated fluid flow and heat transfer processes involved in any heat exchanger can be examined by CFD software, Simscale packages include sophisticated user interfaces to input problem parameters and to examine the results. CFD codes in simscale contain three main elements: (i) a pre-processor, (ii) a solver and (iii) a post-processor. Pre-processing consists of the input of a flow problem to a CFD program by means of definition of the geometry of the region of interest: the computational domain, grid generation—the subdivision of the domain into a number of smaller, non-overlapping sub-domains: a grid (or mesh) of cells (or control volumes or elements), selection of the physical and chemical phenomena that need to be modelled, definition of fluid properties, specification of appropriate boundary conditions at cells which coincide with or touch the domain boundary. Solver uses the finite control volume method for solving the governing equations of fluid flow and heat transfer. Post-processor shows the results of the simulations using vector plots, contour plots, graphs, animations.

The main objective of the CFD study was to investigate the effect of buried pipe material on the performance of the ETHE system (for this two materials, mild steel and PVC were considered) and also to study the effect of air velocity on the performance of the EPAHE system. In the study it was assumed that air is incompressible and subsoil temperature remains constant since the penetration of the heat from the surface of the soil

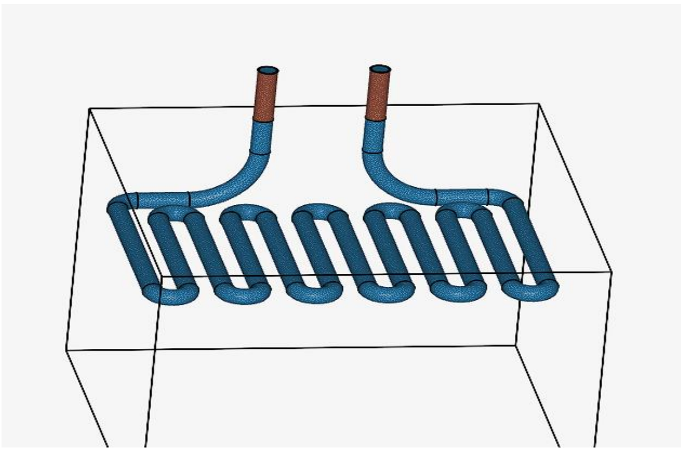

Figure 3. Shows 3-d model meshing for analysis

SIMULATION

The 3D model has been developed in SOLIDWORKS software's, version-2023. After a creating 3D model. Analysis of the earth tube heat exchanger is done with SIMSCALE software. It shows the flow of fluid and rate of heat transfer (heat transfer between soil and fluid) in ETHE. The fluid goes through basic set up of the wizard, adding lids on the inlet & outlet, assigning goals for the temperature drop, and viewing a few results. Heat transfer between soil to earth tubes to fluid is observed as shown in the above analytical model. A temperature drops of 26°C was observed by this simulation

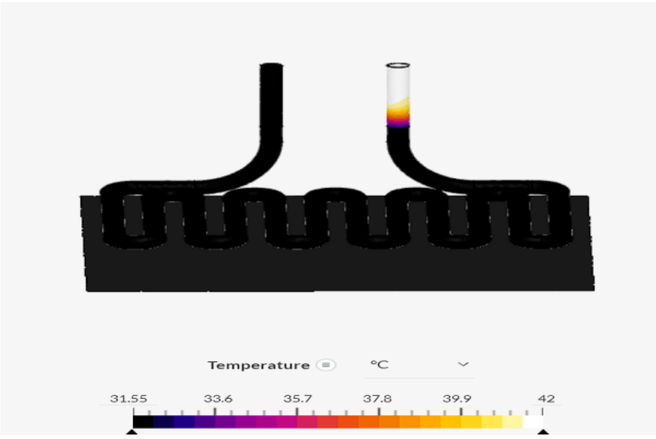

Figure 4. Shows 3-d analysis of pvc pipe in simscale

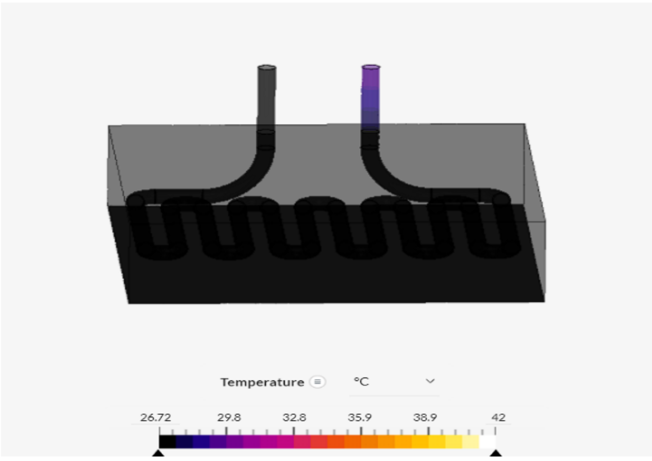

Figure 5. Shows 3-d analysis of copper pipe in simscale

CONCLUSIONS:-

In designing an earth heat tube exchanger, the choice of material significantly impacts both the cost and effectiveness of the system. For an economical solution, PVC pipes are a viable option due to their affordability, ease of installation, and satisfactory thermal conductivity for many residential applications. PVC is durable and resistant to corrosion, making it a cost-effective choice for budget-conscious projects without compromising basic performance.

However, for those seeking higher effectiveness and superior thermal performance, copper tubes are the preferred choice. Copper's excellent thermal conductivity ensures more efficient heat transfer, leading to better overall system efficiency. Although the initial cost is higher compared to PVC, the long-term benefits of enhanced performance and durability can justify the investment, particularly in applications where maximizing energy efficiency is critical.

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