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EARTH TUBE HEAT EXCHANGER

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Abstract:

The focus of this study is on how well Earth Tube Heat Exchangers work in heating, ventilation, and air conditioning (HVAC) systems. ETHE may be used for either heating or cooling by using the "nearly constant" temperature of the ground. The "near-constant" ground temperature may be used in two ways: first, to cool a building by dissipating excess heat, and second, to warm the building. The exit temperature of the air was determined using ETHE (), which is a function of many transfer units (NTU). An earth-air heat exchanger's efficiency is described by the dimensionless group NTU. It was the cooling test that was used for all studies since ETHE wasn't ready for the input parameter until the spring session. ETHE is a PVC pipe with a nominal diameter of 10.6 cm and a wall thickness of 3 mm. It has a length of 19.22 meters. The location of ETHE is buried two meters underneath. A 125-watt fan forces fresh air through it. The researchers analyzed data from an experimental setup in Bhopal, India, based on the static mean temperature of the air at the intake for the three consecutive summer months of March, April, and May (32.2, 37.8, 40.3 0C) (Central India). When the output velocity is raised and the temperature difference is maximized, the system functions most efficiently.

Keywords — **Earth Tube, Heat Exchanger, Effectiveness, Number of the transfer unit.**

1. INTRODUCTION

An earth tube heat exchanger (also known as a ground-coupled heat exchanger or earth-air heat exchanger) is a passive cooling and heating system that uses the thermal mass and constant temperature of the earth to regulate the temperature of a building. The system consists of one or more buried pipes or ducts that are buried underground and connected to the building's ventilation system. Air is circulated through the pipes, where it is either warmed or cooled by the earth's temperature, depending on the season. In the summer, the air is cooled by the earth, while in the winter, it is warmed. Earth tube heat exchangers are a sustainable and energy-efficient alternative to traditional HVAC systems, as they use the constant temperature of the earth to help regulate the temperature of a building. They also reduce the need for energy-intensive heating and cooling systems, leading to lower energy bills and reduced carbon emissions. However, earth tube heat exchangers require careful design and installation to ensure optimal performance and prevent issues such as moisture buildup, air quality problems, and other potential hazards. It is recommended to consult with a qualified HVAC professional before installing an earth tube heat exchanger system.

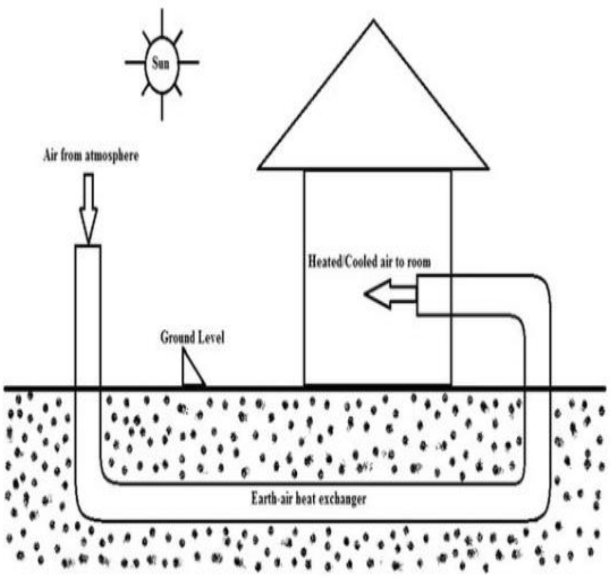

Figure-1: Earth Tube Heat Exchanger.

1.1. PRINCIPLE OF EARTH TUBE HEAT EXCHANGER

An earth tube heat exchanger, also known as a ground cooling and heating system that uses the constant temperature of the earth to regulate the temperature of a building. The principle of that the ground temperature remains relatively constant throughout the year, typically between 10-16°C (50-60°F) in most climates. This temperature is warmer than the outside air temperature during the winter and cooler than the outside air temperature during the summer. The system consists of a series of underground pipes or tubes buried below the frost line, usually around 1.5-2 meters (5-6 feet) deep. The tubes are made of materials such as PVC or high-density polyethylene and are buried in a horizontal or vertical configuration depending on the site conditions. During the summer, hot air from the building is drawn into the tubes via a fan or natural convection. The air is cooled as it travels through the heat to the surrounding soil, which acts as a heat sink. The cool air is then ducted into the building, providing natural air conditioning. outside air is drawn into the tubes and is warmed b heat source. The warm air is then ducted into the building, providing natural heating. Overall, an earth tube heat exchanger can significantly reduce the energy required for cooling and heating a building, resulting in lower energy bills and a reduced carbon footprint.

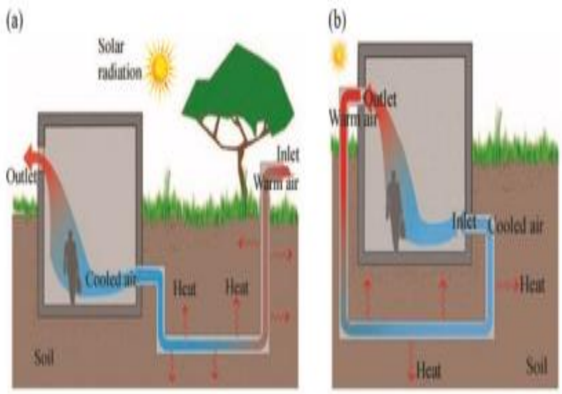

Figure-2: Principle of Earth Tube Heat Exchanger.

1.2. TYPES OF EARTH TUBE HEAT EXCHANGERS

There are two main types of Earth Tube Heat Exchangers:

1. **Horizontal Earth Tube Heat Exchanger:** This type of system consists of a series of pipes buried horizontally in the ground, typically at a depth of 1.5-2 meters. The pipes are usually made of high-density polyethylene (HDPE) or PVC, and they can be arranged in a variety of configurations, such as a single loop or multiple loops. The incoming air is drawn through the pipes, which are cooled or heated by the surrounding soil, before entering the building.
2. **Vertical Earth Tube Heat Exchanger:** In this type of system, pipes are installed vertically in boreholes drilled into the ground, typically to a depth of 30-100 meters. The pipes are connected to a central air handling unit (AHU), which circulates the indoor air through the pipes and back into the building. As with the horizontal system, the soil surrounding the pipes provides the heat exchange medium. Both horizontal and vertical Earth Tube Heat Exchangers can be used for cooling in the summer and heating in the winter, and they can be combined with other HVAC systems for greater efficiency. They are also relatively low-cost and require little maintenance, making them an attractive option for sustainable building design.

2. METHODOLOGY

In the section on the methodology, we will know the parameter of the pipe, temperature, method of analysis, etc. After analyzing the heat exchanger when the system was operating at the highest possible level of efficiency that it can attain, the optimal temperature for the output was discovered and identified. The tables that follow explain how variations in the airflow velocity that are created by the ETHE system impact the output air temperature. These changes are brought about by the ETHE system. An Elementary Heat Exchanger Analysis was carried out, and the findings indicated that as the air velocity increased, so did the air temperature of the air that was exiting the ETHE system. This was discovered after the findings of the Elementary

Heat Exchanger Analysis showed that the air temperature increased with the air velocity. The results of the Simple Heat Exchanger Study demonstrated that the air temperature rose with the air velocity, which led to the discovery of this relationship between the two variables. This phenomenon takes place as a direct result of the increased airflow velocity, which shortens the amount of time that the air is in contact with the ground. This is the root cause of the occurrence of the phenomenon.

$$\dot{m} = \frac{\frac{\pi}{4} D^2 \rho v_a}{N_p}$$

$$Re = \frac{vD}{\nu}$$

$$Nu = 3.66 + \frac{.0668\left(\frac{D}{L}\right) Re\ Pr}{1 + .04\left[\left(\frac{D}{L}\right) \times Re\ Pr\right]^{0.66}}$$

$$h = \frac{Nu.k}{D} \quad (4)$$

$$R = \frac{1}{U} \quad (5)$$

$$R_{convec} = \frac{1}{(2\pi hLr_1)} \quad (6)$$

$$R_{cond/tube} = \frac{\ln\left(\frac{r_2}{r_1}\right)}{(2\pi Lk_p)} \quad (7)$$

$$R_{cond/tube\text{-}soil} = \frac{\ln\left(\frac{r_3}{r_2}\right)}{(2\pi Lk_s)} \quad (8)$$

$$\varepsilon = \frac{T_{out} - T_{in}}{T_{wall} - T_{in}} = 1 - e^{-(hA/\dot{m}C_p)} \quad (9)$$

$$NTU = \frac{hA}{\dot{m}C_p} \quad (10)$$

$$Q_h = \dot{m}C_p(T_{out} - T_{in}) \quad (11)$$

$$COP = = mC_p(T_{in} - T_{out})/\text{Power Input} \quad (12)$$

The parameter of pipe and air for the earth tube heat exchanger is given below in the form of the table:

Table-1: Input Parameter.

Serial Number	Name of Parameter	Value
1	Temperature of wall	25.2 Degree Celsius
2	Diameter of Pipe	0.106 m
3	Thickness of Pipe	0.003 m
4	Internal Radius	0.05 m
5	External Radius	0.053 m
6	Velocity of Air	1.8, 3.5,5 m/s
7	Kpipe	0.16 W/m-K
8	Ksoil	0.54 W/m-K
9	Kair	0.0271 W/m-K
10	Cp (air)	1006 j/kg-K
11	Density of air	1.126 Kg/m3
12	Kinematic velocity	0.00001661 m2/s
13	Power	125 watt

3. RESULT AND ANALYSIS

In the result and analysis, we will study the result which comes out after the analysis of these earth tube heat exchangers by using the above formula.

Table-2: The Variability of Elementary Parameters with Velocity.

Parameter	Air flow velocity=1.8 m/s	Air flow velocity=3.5 m/s	Air flow velocity=5 m/s
Re	11487	22336	31908
Nu	35.61	60.63	80.65
h (w/m^2-k)	9	15.5	20.62
U (w/m^2-k)	30.67	40.81	45
NTU	2.53	1.6	1.23
ε	0.92	0.8	0.7
ṁ (kg/s)	0.019	0.037	0.053

Table-3: Simple method for calculating outlet temperatures, heat flow, and COP at different velocities.

Month	T_{in} (°c)	Air flow velocity = 1.8 m/s			Air flow velocity=3.5 m/s			Air flow velocity=5 m/s		
		Elem.T_o (°c)	Q (w)	COP	Elem.T_o (°c)	Q (w)	COP	Elem.T_o (°c)	Q (w)	COP
March	32.2	25.7	126.2	1.0	26.6	208.4	1.6	27.3	261.25	2
April	37.8	26.2	225.2	1.8	27.7	376	3	28.9	474.53	3.8
May	40.3	26.4	269.87	2.2	28.2	450.3	3.6	29.7	565.17	4.5

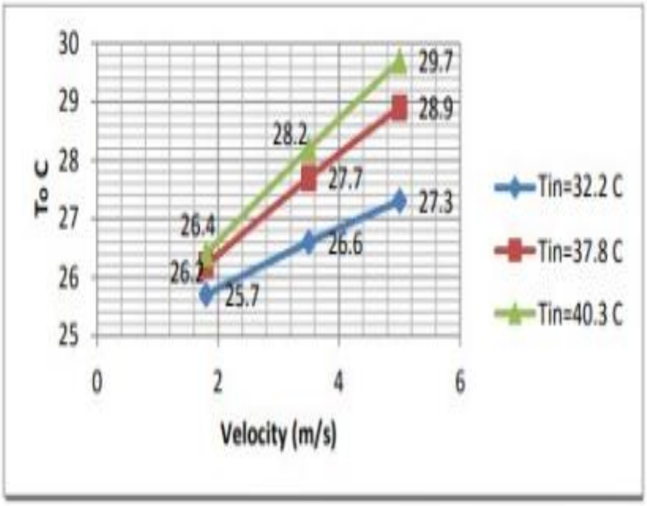

Figure-3: Input and velocity affect outlet temperatures.

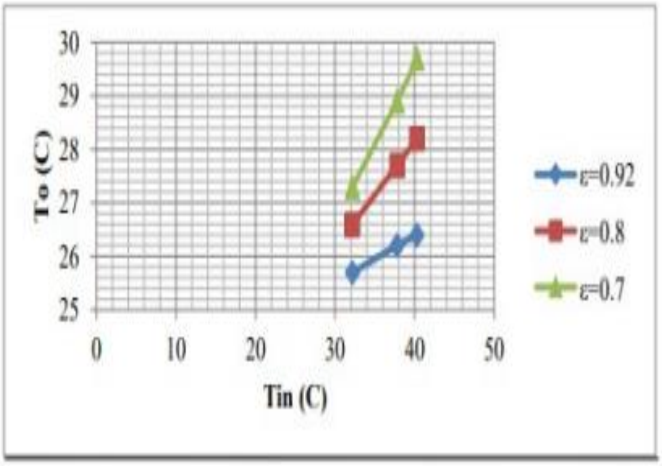

Figure-4: Different ETHE efficacy outlet temperatures.

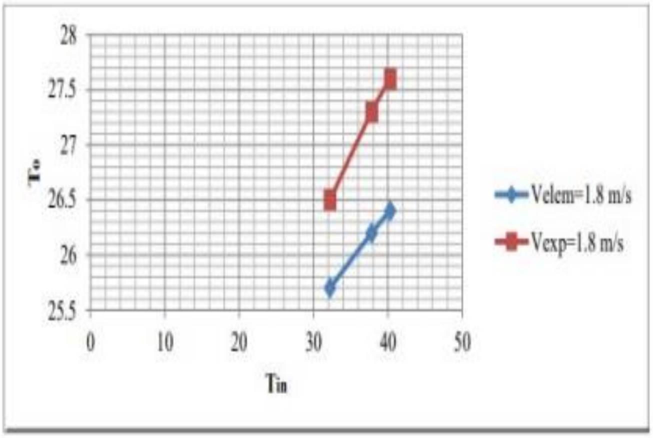

Figure-5: Air velocity (1.8m/s) comparison.

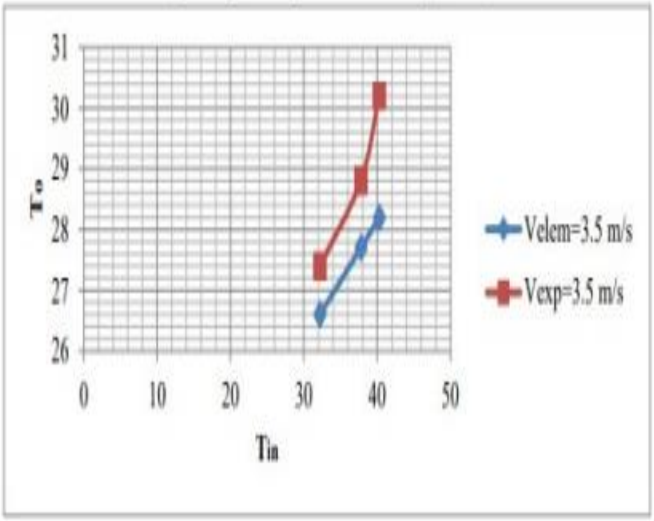

Figure-6: Air velocity (3.5 m/s) comparison.

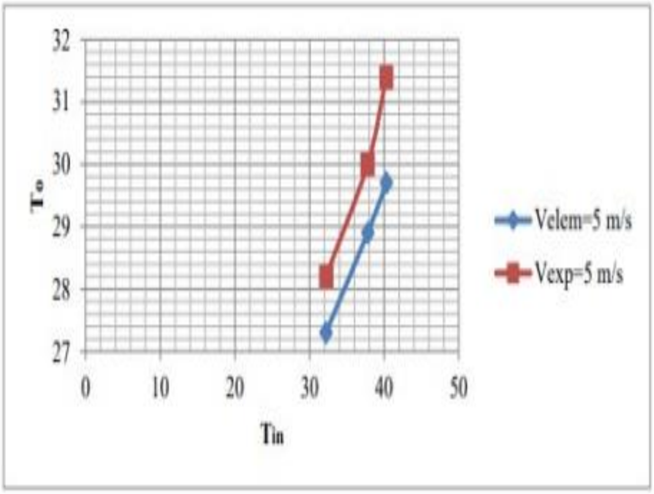

Figure-7: Air velocity (5 m/s) comparison.

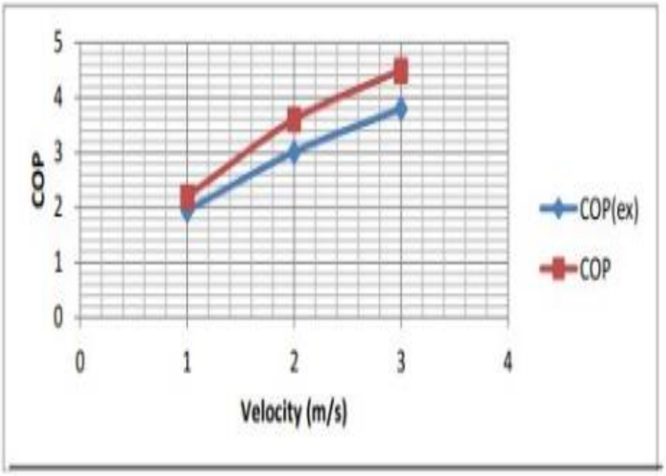

Figure-8: Tin = 40.3 degree Celsius comparison.

4. CONCLUSIONS

Several hopeful findings were shown in the comparison charts that were presented in the chapter that came before this one. When the outlet flow velocities are in the range of 1.8 m/s to 5 m/s, the temperature within the pipe, which has a length of 19.22 meters and a diameter of 0.106 meters, rises by 5.90C-10.9C. Here is a summary of the findings. At 1.8 meters per second, the temperature differential is the biggest; yet, 5 meters per second produces the most efficient cooling. When the output velocity is raised from 1.8 to 5 meters per second, the system's coefficient of performance (COP) has a range that may be anywhere from 2.2 to 4.5. When both the output velocity and the temperature differential are at their highest, the technology operates at its most effective level. With a temperature differential of 13.9 degrees Celsius and an outlet velocity of 1.8 meters per second, the efficacy was at its highest point (0.92). Despite this, the performance was not maximized since there was not enough cooling rate; accordingly, the maximum COP 4.5 was obtained at a velocity of 5 meters per second with effectiveness () of 0.7 and a temperature differential of 10.9 degrees Celsius. The findings of this research might potentially be put to use in the construction of such systems, which would take into account both needs and environmental factors. The results may contribute to the design of such systems, making it possible to pick pipe types, diameters, materials, and climatic conditions with more latitude. As a consequence of this, it is now feasible to analyze a variety of alternative permutations before choosing the pipe size, material, and fluid type that would be most suitable. As was said before, the performance of the ETHE system is affected by operational aspects.

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