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ANALYSIS OF EARTH TUBE HEAT EXCHANGER

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Abstract

The growing global demand for energy is amplifying the need for the development of sustainable and energy efficient systems lead to the use of ETHE. The implementation of passive technology in buildings for space heating and cooling to reduce the energy consumption is relatively new in Indian climatic conditions.

The temperature of earth at a certain depth about 2 to 5 m 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 tube heat exchanger (ETHE) can fulfill in both purpose heating in winter and cooling in summer.

Keywords: ETHE, Close loop, Heat Exchanger, Temperature, Pipe.

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1. Introduction

Earth tube heat exchanger is an underground heat exchanger that can capture heat from and dissipate heat to the ground. They use the earth near constant subterranean temperature (undisturbed temperature) to warm or cool air or other fluids for residential, agricultural or industrial uses. They are also called earth tubes or earth-air heat exchangers or ground tube heat exchanger.

Earth tubes are often a viable and economical alternative or supplement to conventional central heating or air conditioning systems since there are no compressors, chemicals or burners and only blowers are required to move the air. These are used for either partial or full cooling and their use can help building meet passive house standards.

In the case of cooling a building, the ground is the heat sink, and the building to be cooled acts as heat source. In the case of heating, these functions are reversed- the ground becomes the heat source and the building heat sink. Heat is extracted from or rejected to the ground by means of buried pipe, through which a fluid flows. The buried pipe is commonly called ground loop heat exchanger.

- The earth tube heat exchanger systems utilize the heat-storing capacity of earth.
- The fact that the year round temperature approximately four meters below the surface remains almost constant throughout the year. That makes it potentially useful in providing building with air-conditioning.
- It depends on the ambient temperature of the location, the eat system can be used to provide both cooling during the summer and heating during winter.
- The ground temp remains constant and air if pumped in a approximate amount that allows sufficient contact time for the heat transfer to the medium attains the same temperature as the ground temperature.

Figure 1: View of the ETHE buried at 3m depth. [1]

In the present study, the following assumptions are considered:

- For low velocities (Generally less than 100 m/s) air is considered to be incompressible.
- The soil properties are homogenous in nature.
- The soil temperature is constant throughout the length.
- Hydraulic diameter and length of pipe is equal for all geometries.

2. Literature Review

The achievable performances of energy by using an earth tube heat exchanger for controlling air-conditioning for building is evaluated for nine months in a whole year. Earth Tube Heat Exchanger (ETHE) is used to cool down the zone in the hot days and to heat the zone in cold days is investigation by Dastan Zrar Ghafoor. [1].

High velocity of air reduces the temperature difference between outlet and inlet, so velocity in between 2 - 5m/s more suitable. At a depth of 1.5 m EUT is becomes stable so depth taken should be more than that 2m is sufficient to get required effect. Air quickly reached to the soil temperature so larger tube diameter is not needed is review by Nilesh S. Shelar et.al. [2].

The required tube installation length for the ewhe compared to an EAHE but the tubes are much smaller. A case studies using to CHE in parallel showed further improvement of the ETHE by Sharda Chauhan et.al. [3]. It confirms the objective that the appropriate pipe geometry is the corrugated pipe geometry for optimum temperature variation. Also, reasserts that the EAHE system can be used for space heating as well as cooling in Indian climatic conditions. In order to obtain maximum temperature reduction corrugated pipes can be laid underground for further experimentation in this field is studied by Namrata Bordoloi et.al. [4].

For the pipe of 9 m length and 0.05 m diameter, temperature rise of 3.2C-6.1C has been observed for the outlet flow velocity 11m/s. The maximum COP obtained in summer climate is 2.817 at time 14:00 and the maximum COP obtained in winter climate is 1.321 at time 22:00 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. If the length of pipe is less than 50-70m the system is useless because the cooling rate or heating rate is so small. If the blower speed is high and the length of pipe is less than the temperature difference inlet and outlet is very small. This work can be used as a design tool for the design of such systems depending upon the requirements and environmental variables. The work can aid in designing of such systems with flexibility to choose different types of pipes, different dimensions of pipes, different materials and for different ambient conditions. So this provides option of analyzing wide range of combinations before finally deciding upon the best alternative in terms of the dimension of the pipe, material of the pipe, type of fluid to be used. The performance is studied by Ashish Kumar Chaturvedi et.al. [5].

The present study reviews the previously conducted studies in terms of performance assessment with effects of various parameters like material of construction, depth from earth surface, velocity of air and length of pipe is observed by Dheeraj Sardana et.al. [6].

3. Working Principle

3.1 Closed loop system

Closed loop systems are also known as earth coupled system as shown in figure 2. Air sucked from inlet travels through a loop of pipes buried underground and extracts the heat from ground. The ground loops are arranged either vertically or horizontally. The vertical loops are more expensive than horizontal loop. Closed loop are efficient than open loop system. Closed loop system reduces the problem of humidity.

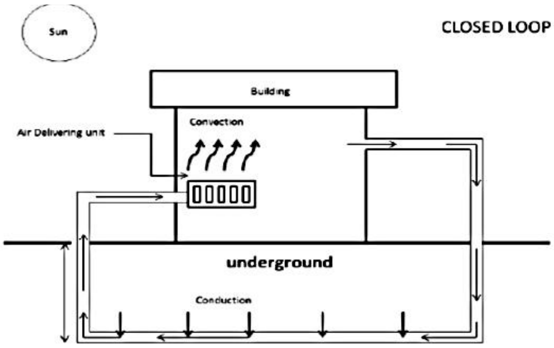

Figure 2: Closed Loop System. [4]

3.2 Pipe Layout Arrangement

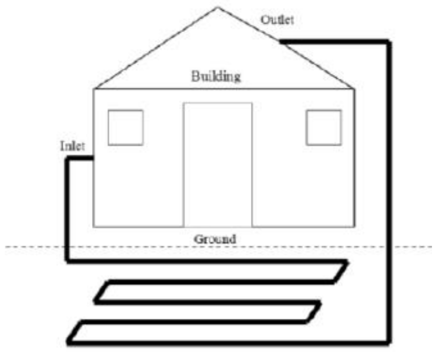

Figure 3: Horizontal Loop System.[4]

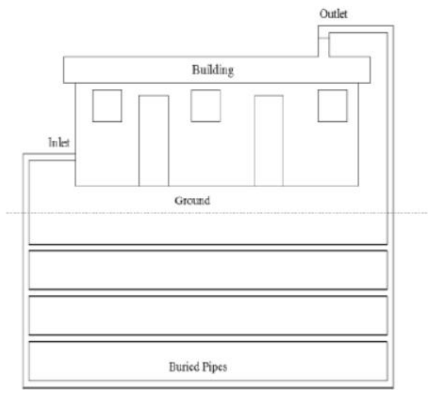

Figure 4: Parallel Tube.[4]

3.3 Tube Depth

The ground temperature is defined by the external climate and by the soil composition, its thermal properties and water substance. The earth temperature fluctuates with time, but the amplitude of the fluctuation diminishes with increasing depth of the tubes, and deeper in the ground the temperature converges to a practically constant value throughout the year.

On the basis of temperature allocation, ground has been notable into three zones:

- Surface zone: this zone is extended up to 1m in which ground is very sensitive to external temperature.
- Shallow zone: this zone is extended up to 1-8 m depth and temperature is almost constant and remains close to the average annual air temperature.
- Deep zone: this zone is extended up to 20 m and ground temperature is practically constant. Soil temperature at a depth of about 10 feet or more stays fairly constant throughout the year and stays equal to the average annual temperature. After a depth of 3-4 m in the ground, temperature remains nearly constant.

3.4 Tube Length

Tube diameter and air flow rate: the total surface area of the ground coupled air heat exchangers is a very important factor in a overall cooling capability, which can be improved by two ways, moreover increasing the tube length or tube diameter. Optimum tube diameter varies widely with tube length, tube costs, flow velocity and mass flow speed. A diameter should be selected to facilitate it can balance the thermal and economic factors for the best performance at the lowest cost.

The optimum is determined by the actual cost of the tube and the excavation. Excavation costs in particular vary greatly from one location and soil type to another. The optimum tube length was determined by passing the air from the blower at different lengths. The air was passed through the inlet at the minimum speed of the blower i.e. 7 m/s and at the length of 9 m, the outlet speed was 1.8 m/sec, any additional increase in length used to decrease the velocity at opening which was not required. The 5 cm diameter pipe was considered for the experiment.

3.5 Tube Material

Various factors need to be considered while deciding upon the material of the pipe for this system. There can be many options while selecting the material of the pipe to be used with the system. As the pipe has to be buried underground, it is not easy to replace the pipe often. Hence the longevity of the pipe is of utmost importance while taking care of the heat transfer characteristics of the arrangement. There was a broad range of materials on hand for the selection for use in our system.

Mild steel (ms): Mild steel is untreated and usually hot or cold rolled or in the case of pipe extruded even as molten. Low carbon substance and rusts in moist weather and can be bent easier than other steel. It's not black tube used for gas, it's not case toughened with cyanide, it's not galvanized through zinc plating, it's not blued similar to used for guns, it's not cast like cast iron furniture. It's nearly all reasonable type of steel.

Mild steel pipe refers to the content of less than 0.25% carbon steel because of its low power, low stiffness and soft. It includes nearly all of the part of ordinary carbon steel and high-quality carbon structural steel, typically without heat action used in engineering structures, some carburizing heat treatment and other mechanical parts required for wear.

3.6 Factors Affecting Thermal Conductivity

- Moisture content: most notable impact on thermal conductivity.
- Thermal conductivity increases with moisture to a certain point (critical moisture content).
- Dry density of soil: as dry density increase thermal conductivity increase.
- Mineral composition: soils with higher mineral content have higher conductivity. soils with higher organic content have lower conductivity.

3.7 Blowers

Blowers can achieve much higher pressures than fans, as elevated as 1.20 kg/cm2. They are too used to manufacture negative pressures for industrial vacuum system. The centrifugal blower & the optimistic displacement blower are two main types of blowers, which are described below

Centrifugal Blowers: Centrifugal blowers look more like centrifugal pumps than fans. The impeller is naturally gear-driven and rotates as rapid as 15,000 rpm. In multistage blowers, air is accelerate as it go through every impeller. In single stage blower, air does not take numerous turns, and therefore it is more efficient.

Positive-Displacement Blowers: Positive displacement blowers have rotors, which "trap" air and push it throughout lodging. These blowers offer a stable volume of air even if the system force varies. They are especially suitable for applications prone to clogging, since they can produce enough pressure (typically up to 1.25 kg/cm2) to blow clogged resources free. They revolve much slower than centrifugal blowers (e.g. 3,600 rpm) and are often belt driven to facilitate speed changes.

3.8 Design of Proposed System

The proposed system consists underground earth tubes, blower and measuring instruments Pipes are to be buried at 3-5m depth from the ground level, as we can see from the demonstrated figure.

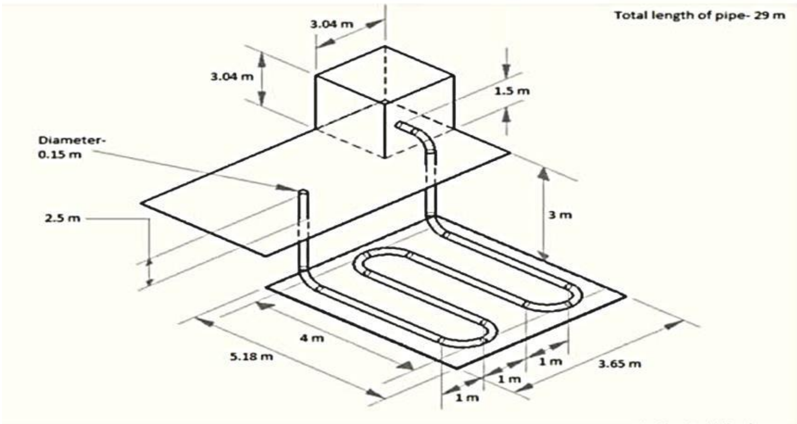

Figure 5: Design of Proposed System.

4. Result and Discussion

4.1 Effect of Velocity of Air inside Pipe

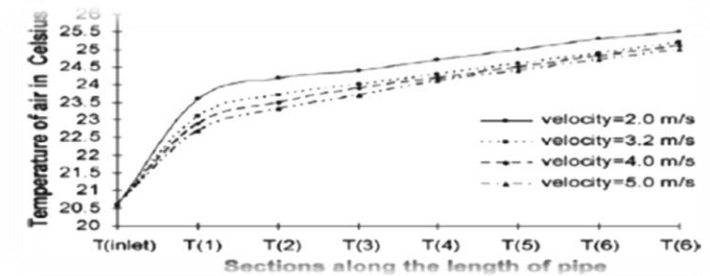

Figure.6: Effect of Velocity of Air inside Pipe. [2]

The effect of velocity of air inside pipe is shown in fig. 6. The reduction in temperature of air at the exit of pipe due to increment in air velocity occurs because when the air velocity is increased from 2.0 to 5.0 m/s, the convective heat transfer coefficient is increased by 2.3 times, while the duration to which the air remains in contact with the ground is reduced by a factor of 2.5. Thus the later effect is dominant and therefore, fewer rises in temperature is obtained at air velocity 5.0 m/s than the 2.0 m/s. At high speeds due to reduction in time of contact the performance gets reduce.

4.2 Effect of Tube Length

It can be concluded that up to some extent length matters after a certain length no improvement in the performance is found however large its length may be. It can be inferred that, for all the considered climates, lengths of about 10 m are unsatisfactory, while significant advantages do not occur for lengths over 70 m. The effect of temperature on tube length is graphically represented in fig. 7.

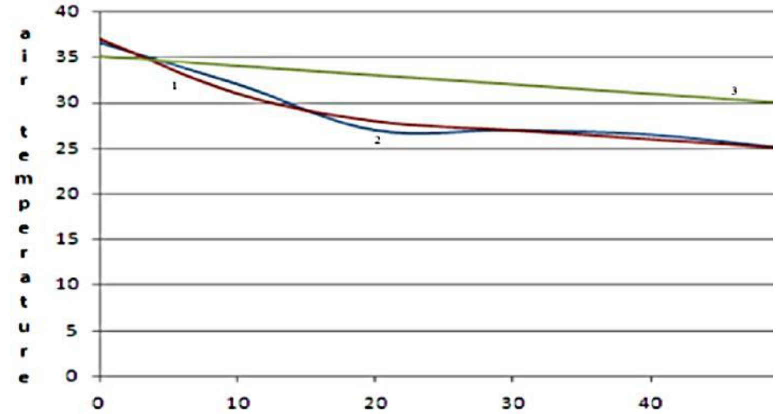

Figure.7: Effect of Tube Length. [2]

4.3 Effect of Tube Depth

Figure 8: Effect of Tube Depth. [2]

The ground temperature is affected by the external climate and soil composition its thermal properties and water content. The temperature of soil fluctuates but become stable after some depth. This temperature remains same throughout the year. From fig. 8 it is clear that after a depth of 1.5 meters this temperature becomes stable. The depth beyond 3.5 m unnecessarily increases the cost because we don’t get temperature gradient beyond this depth.

4.4 Effects of Tube Diameter

Cooling capacity depends on the overall surface area which is a keyway in designing it. This can be affected in two ways by changing length and diameter of the pipe. From fig. 9, it is observed that on increasing the diameter the mass flow rate gets reduced and more length increases pressure drop and increases the blower input. According to (epec2002) the optimum solution is the parallel tube of proper length and diameter are used. The air quickly reached the soil temperature so larger tubes are not needed.

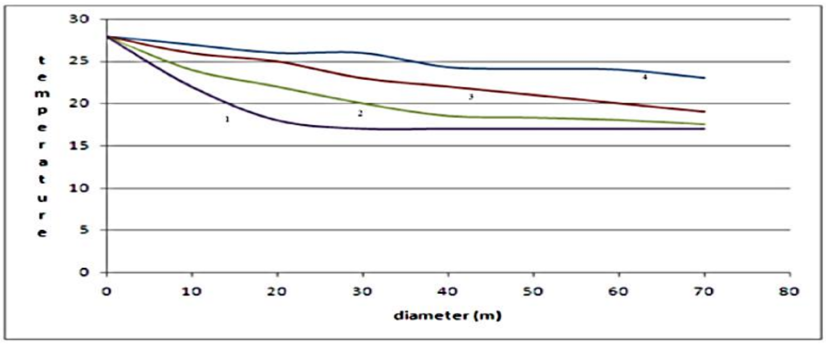

Figure 9: Effect of Tube Diameter. [2]

4.5 Temperature Profile

No	Season	Ambient air temperature	Soil temperature	Space temperature
1	Winter	12ºc-20ºc	22ºc-28ºc	24ºc-26ºc
2	Summer	40ºc-45ºc	25ºc-30ºc	25ºc-28ºc

This paper focused on the utilizing of the geothermal energy to control the ventilation of the standard zone. The supply air temperature to the standard zone is considered to be approximately 25˚c. The temperature of the ground can be considered as a basic data for installing the ETHE so as to predict the ground temperature during the air passage through the pipe, thermocouples are installed at a depth of 3m. It can be achieved that the temperature increases according to the length of the pipe, whereby the relation is proportional. Measurements present that the temperature is stable during the certain time, and remains relatively in the same level. At the depth of 3 m, the temperature is about 23˚c if compared with the ambient temperature which is around 38˚c in the summer; where, in the winter the ground temperature is about 20˚c compared with the outdoor temperature which becomes below 5˚c.

The materials of the pipe are plastic, but if it is replaced with other materials having higher thermal conductivity to get higher heat transfer, it will be significantly more effective. Research gap: it has been already noted that the effectiveness of ETHE depends on depth of the pipe installed, thermal diffusivity of the soil, length and diameter of the pipe, ambient temperature of a certain location, thermal conductivity of the pipe and air flow velocity. Adequate studies have already been conducted on ETHE considering the above-mentioned parameters. But least studies have been conducted considering the pipe geometry and materials. This research work focuses on the variation of temperature for different duct geometries and different pipe material.

The ETHE systems have several advantages over the conventional system. They are:

- Air is used as working fluid.
- It consumes less energy as compared to prevailing conventional systems.
- Design is simple hence requires less maintenance and low cost.
- Pollution is minimized as no refrigerant or compressors are used in this system.
- ETHE based systems cause no toxic emission.

The disadvantages are:

- Require large space to make setup.
- Initial cost high.

5. Conclusion

- ETHE technology is an emerging technology and has many advantages over conventional systems. ETHE technology finds its application specially in space heating / cooling, greenhouses, snow melting etc.
- This technology can also be adapted for energy saving as it saves around 50% more energy than conventional system. Nowadays, hybrid ETHE are also used for increasing the efficiency of these systems.

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