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TO INVESTIGATE THE EFFECT OF EARTH TUBE HEAT EXCHANGER COOLING OF ENVIRONMENTAL AIR

Ankit Tiwari[1], Prof. Pawan Kumar Tiwari[2]

[1]*M. Tech. Scholar, Department of Mechanical Engineering Patel college of science and technology, Bhopal*
[2]*Assistant Professor, Department of Mechanical Engineering Patel college of science and technology, Bhopal*

ABSTRACT

The use of ground coupled heat exchanger (GCHE) systems is increasing worldwide. They are mainly used for space conditioning, water heating, agricultural drying, bathing, swimming, etc. They reduce cooling load in summer and heating load in winter. GCHE systems make available excellent scope to conserve significant amount of primary energy and thus mitigating the impact on environment through emission reduction. This paper reviews the experimental and modeling studies carried out on GCHE systems. The reviewed literature focuses on performance of both types of GCHE systems viz. earth–air heat exchanger (EAHE) and ground source heat pump (GSHP) systems and brings out their merits and demerits.. Experimental investigations were done on the experimental set up in Patel college of science and technology, Bhopal. Effects of the operating parameters i.e. air velocity and temperature on the thermal performance of horizontal ground heat exchanger (GI Pipe & Copper Pipe) have been studied. Forthe pipe of 9m length and 0.05m diameter, temperature falling GI Pipe of 3.930C-12.60C in hot weather and temperature rising GI Pipe of 6oC-10oC in cold weather Same as temperature falling Copper Pipe of 3.930C-12.60C in hot weather and temperature rising Copper Pipe of 6oC- 10oC in cold weather have been observed for the outlet flow velocity 11 m/s. At higher outlet velocity and maximum temperature difference, the system is most efficient to be used.

1. INTRODUCTION

The way towards energy and environment sustainability is the incremental adoption and promotion of renewable energy technologies, practices and policies [1]. Green building control strategies use various concepts of natural heating, ventilation and air conditioning [2,3]. GCHE technique is one of them. It is an underground heat exchanger that can absorb from/release heat to the ground. The underground temperature remains relatively constant throughout the year or all year average of sol air temperature of its ground surface [4,5]. This constant temperature characteristic is due to high thermal inertia of the soil and as the depth increases, effect of temperature.

Earth-air heat exchangers have been used in agricultural facilities (animal buildings) and horticultural facilities (greenhouses) in the United States over the past several decades and have been used in conjunction with solar chimneys in hot arid areas for thousands of years, probablybeginning in the Persian Empire. Implementation of these systems in Austria, Denmark, Germany, and India has

Become fairly common since the mid-1990s, and is slowly being adopted in North America. fluctuations of the ground surface is reduced. Due to time lag between the temperature variations at the surface of the ground and below the ground, at a sufficient depth, temperature below the ground is always higher than that of the outside temperature of air in winter and is lower in summer. This temperature difference can be used for pre-heating in winter and pre-cooling in summer by installing appropriateGCHE system. Advantages of GCHE systems are highefficiency, stable capacity, good air quality, better thermal comfort, easy control, require simple equipments, low maintenance cost, environment friendly, long term costeffective, tax benefit, and noise free being the undergroundunit. Drawbacks are higher initial cost, limited availability of trained technicians and contractors. Performance of GCHE systems depends on air/liquid flow rate, depth and length of buried pipe/ tube (sufficient for air/liquid to lose the heat to certain extent), material and diameter of pipe/tube, temperature difference between earth and ambient, initial soil temperature, rating of blower fan, and various combinations of pipes.

GROUND COUPLED HEAT EXCHANGER

GCHE systems have multiple primary objectives. These are to achieve the best operational efficiencies, the lowest possible operational cost and run environmentally safe, to have lowest possible initial cost and surface area, to increase interior comfort levels and long-term system durability, to make possible ease of service and maintenance and to earn revenue under certified emission reduction (CER). Sequestration of one ton of carbon dioxide-equivalent (CO_2-e) is represented by one CER unit. Developing country like India can earn additionalrevenue of 234 107 Euros under CER by using GCHE [6]. GCHE systems are preferred to those locations where fluctuation in ground surface temperature level is high and under the demands of reduction of CO_2 released into the atmosphere. According to connection and orientation, itcan be classified as series and parallel, horizontal and vertical. According to flow substance, it can be classifiedas EAHE or underground air tunnel (UAT) and GSHPsystem. EAHE system concept is popularly used in colder countries for space cooling and heating, respectively in summer and winter, shown in Fig. 1 [7]. EAHE systems contain buried pipes in various combinations, in open loop as well as in closed loop. Air is blown through buriedpipes using a properly sized blower fan installed at the entry or exit [8]. EAHE systems are cost effective and having long life but prone to air contamination from bacterial growth, corrosion due to moist/humid air and chemical reaction inside the tunnel may dither public acceptability in residential buildings which needs further investigations. Above drawbacks in adopting EAHE systems are overcome in GSHP systems which are suitablefor space cooling/heating of residential buildings and small commercial offices.

GSHP systems are electrically powered, circulate a heat transfer fluid around a loop of buried pipe, use relatively constant temperature of the earth and transfer heat to or from earth. They can be classified as regular and direct exchange geothermal heating/ cooling system or direct expansion ground-coupled heat pump (DX-GCHP).

DESIGN PARAMETERS

When designing earth tubes, choosing the type of pipe is the first decision. There are a variety of materials to choosefrom, from baked clay tiles, to steel duct work, to common PVC or the most modern HDPE plastics with anti- microbial coatings. Perhaps I will eventually come back and put this in a table, but for now, I will just list some of the pros and cons to each.

Note that the thermal conduction properties of the material do affect the rate that heat conducts thru them, but it doesn't seem to affect the overall performance of the earth tubes. Partially, this may be because the total resistance to thermal conduction includes both the R value and the thickness.

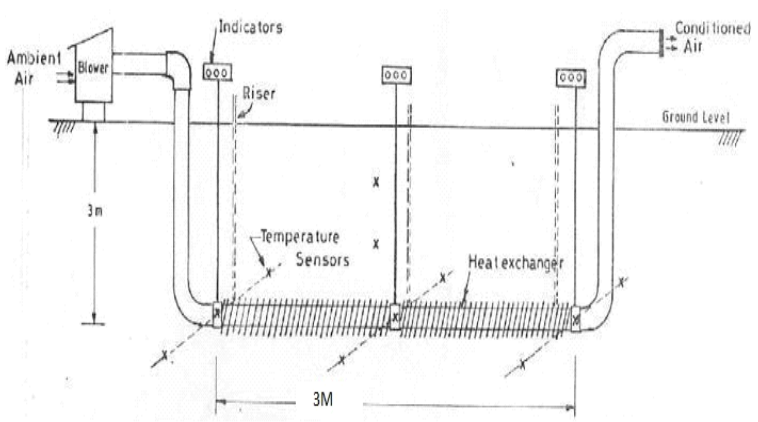
Although concrete conducts heat better than plastic, concrete pipe is typically much thicker and 2 inches of concrete ends up with a thermal resistance similar to 1/4 inch of HDPE. It is also somewhat because a somewhat stable temperature gradient is setup that eventually lets the heat thru. But the real reason the material conductivity doesn't matter very much is because it is the conductivity of the earth that is the bottleneck. Aluminum conducts heat very quickly, but can't draw it from the earth any faster than a plastic pipe can.

More important aspects to consider include durability, cost, ease of installation, environmental concerns and the interior wall friction factor that has a direct effect on the frictional pressure losses of the system.

EXPERIMENTAL SET UP

Description of Set-Up

For the experimental work we used MS pipe of 5 cmdiameter and was buried at a depth of 3meters. A blower was used to drive the air through the pipe which wascirculated throughout the pipe. A vane type anemometer and thermocouple was used to measure the velocity and temperature of the air respectively. The thermocouple wasattached with the Temp. Sensor .Figure



Experimental Result for summer and Winter Season

This work done on the basis of compression of earth tube heat exchanger materials GI and Copper. The Experimental data for GI Pipe pick from research paper Arvind Sen. at al. [51] and for copper pipe data finding with the help of experiment, after that both result are comprises in single plate form.

Cooling Model Test (GI PIPE)

The air velocity was 11 m/s. Velocity was measured by a portable, digital vane type anemometer

The vane size is 66 x 132 x29.2 mm and velocity range 0.3to 45 m/s. The anemometer measures mean air velocity. The volume flow rate of air was 0.0863 m3/s and mass flow rate 0.0269 kg/s. The ETHE system was operated for seven hours a 3days 24, 25&26 MAY-2021) for May Month. The tube air temperature at the inlet, middle and outlet, were noted at the interval of one hour. System was turned on at 10.00 AM and shut down at 5 PM. Tests in May were carried out on 24th, 25th, and 26th 2021). T

	Average Inlet Temp, Middle And Outlet Temp. Of ETHE (MAY -2021)				
Time		Ta=Ti	Tmid	To	COP
10:00		30.73	29.06	26.8	0.851
11:00		34.33	29.16	26.76	1.64
12:00		36.56	29.43	27.13	2.043
13:00		37.63	29.46	27.1	2.281
14:00		40.13	29.66	27.13	2.817
15:00		40	29.63	27.13	2.788
16:00		39.8	29.76	27.2	2.73
17:00		39.6	29.9	27.13	2.702

AVERAGE INLET TEMP, MIDDLE AND OUTLET TEMP. OF ETHE

he ambient temperature on these three days was very similar. The results of the three days were therefore averaged. Table-5.1(a) shows the data, which is reading of three days and Table- 5.1(b) mean of the reading of three days. The ambient temperature started with 30.73oC at

10.00 AM and rise to a maximum of 40.13oC at 2 PM. The temperature of air at outlet was 26.8oC at when system started in 10am.. The outlet temperature was just above thebasic soil temperature (26.6oC). The table also shows the COP values. The maximum COP Achieved at 2pm i.e. 2.702.

EXPERIMENTAL RESULTS (Graphical Representation)

- Time &Inlet Temp. (May-2021)

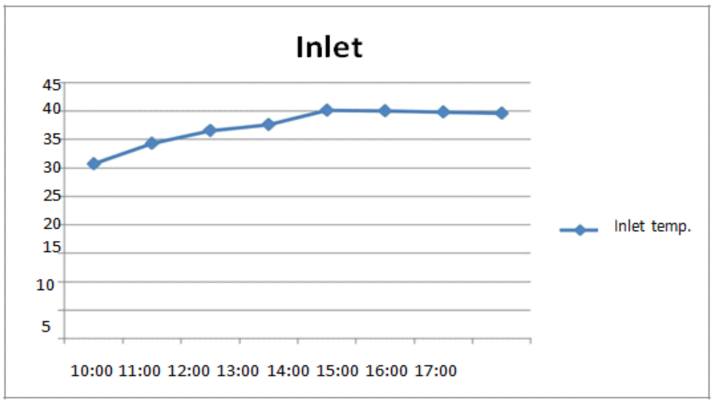


Fig. No. 5.1 Variation of Inlet temperature with time

- Time & Outlet Temp (May-2021)

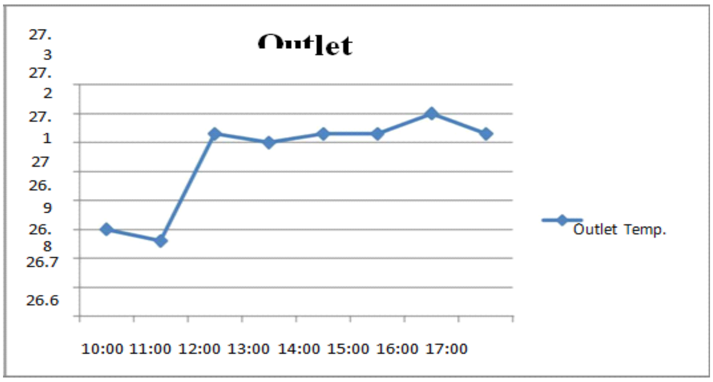


Fig. No. 5.2 Variation of Outlet temperature with time

- Time & Cop (May-2021)

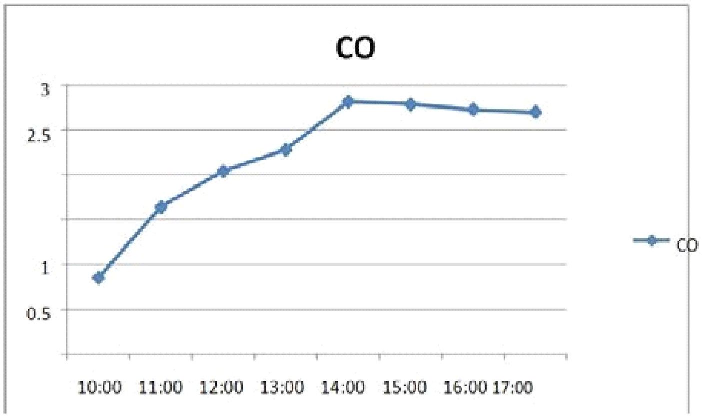


Fig. No. 5.3 Variation of COP with Time

- Time, Inlet, Outlet Temp & Cop (May-2021)

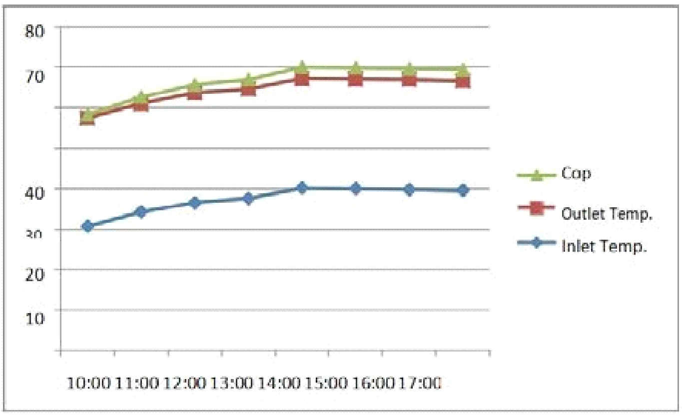


Fig. No. 5.4 Variation of Inlet, Outlet Temp. & COP withTime

5.1(C) COOLING MODEL TEST (COPPER PIPE)

The air velocity was 11 m/s. Velocity was measured by a portable, digital vane type anemometer

The vane size is 66 x 132 x29.2 mm and velocity range 0.3to 45 m/s. The anemometer measures mean air velocity. The volume flow rate of air was 0.0863 m3/s and mass flow rate 0.0269 kg/s. TheETHE system was operated for seven hours a 3days 24, 25&26 MAY-2021) for May Month. The tube air temperature at the inlet, middle and outlet, were noted at the interval of one hour. System was turned on at 10.00 AM and shut down at 5 PM. Tests in May were carried out on 24th, 25th, and 26th may 2021). The ambient temperature on these three days was very similar. The results of the three days were therefore averaged. Table-1(c) shows the data, which is reading of three days and Table- 1(d) mean of the reading of three days. The ambient temperature started with 30.73oC at

10.00 AM and rise to a maximum of 40.13oC at 2 PM. The temperature of air at outlet was 23.63oC at when system started in 10am.. The outlet temperature was just above thebasic soil temperature (26.6oC). The table also shows the COP values. The maximum COP Achieved at 2pm i.e3.6

Average Inlet Temp, Middle And Outlet Temp. OfETHE(MAY- 2021)				
Time	Ta=Ti	Tmid	To	COP
10:00	30.73	27.06	23.63	1.53
11:00	34.33	27.16	23.07	2.44
12:00	36.56	27.04	23.13	2.91

13:00	37.63	27.04	23	3.17
14:00	40.13	27.06	23.13	3.68
15:00	40.00	27.05	23.13	3.65
16:00	39.8	27.07	23.01	3.63
17:00	39.6	27.08	23.16	3.56

Average Inlet Temp, Middle and Outlet Temp. Of ETHE

- EXPERIMENTAL RESULTS (Graphical Representation)
- Time &Inlet Temp. (May-2021)

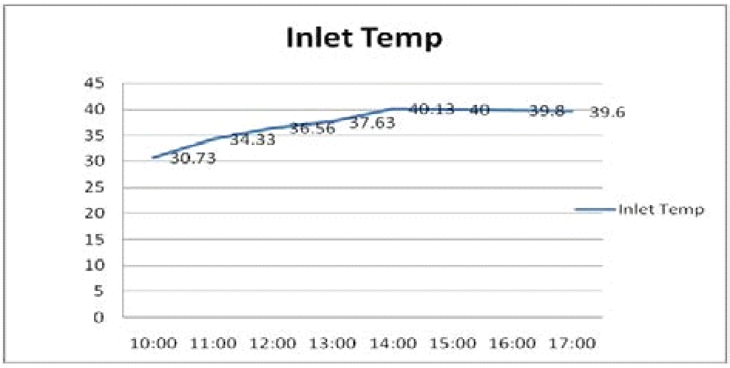


Fig. No. 5.5 Variation of Inlet Temperature with time

- Time & Outlet Temp. (May-2021)

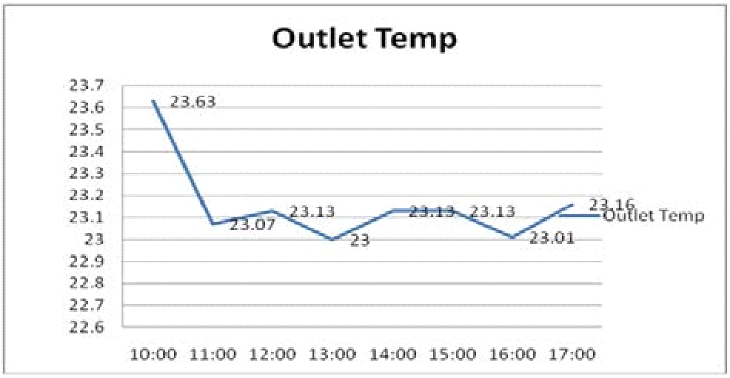


Fig. No. 5.6 Variation of Outlet temperature with time

- Time &Cop. (May-2021)

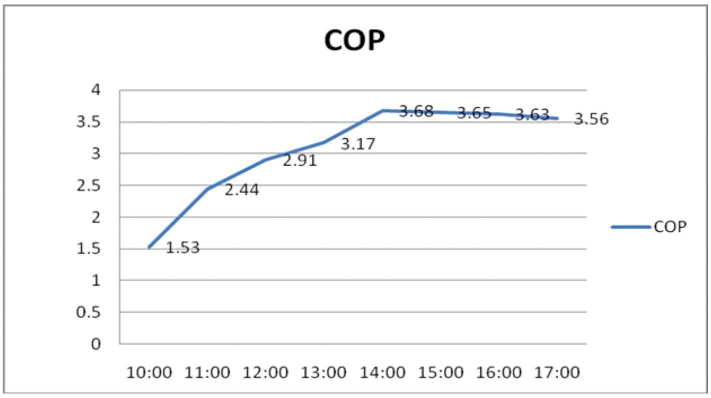


Fig. No. 5.7 Variation of COP with Tim

- Time, Inlet, Outlet, & Cop. (May-2021)

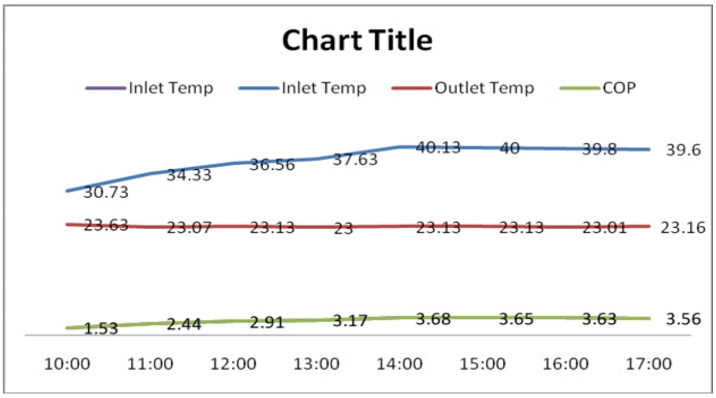


Fig. No. 5.8 Variation of Inlet, Outlet Temp. & COP withTime

5.2(A) HEATING MODEL TEST (GI PIPE):

Heating mode test tests were carried out for three Day of Jan.2022 (02, 03&4th) The system was turned on at 10am and operated for 8 hours continuously, till 5 pm that day. Temperature readings were noted at hourly interval. Here also the conditions on the three consecutive days weresimilar and therefore the results combined. Table 5.2(a) shows the measured data, and Table 5.2(b) which is the mean of three test runs. The ambient temperature started at21oC (10 AM), increasing the highest value 30.05oC at 5 pM.

Average Inlet Temp, Middle And Outlet Temp. of ETHE (Jan2022)				
Time	Ta=Ti	Tmid	To	COP
10:00	21	25.42	27.53	1.41
11:00	22.13	25.54	28.63	1.4
12:00	24.33	25.62	31.43	1.53
13:00	26.53	27.78	34.56	1.74
14:00	27.3	28.46	36.5	1.99
15:00	27.27	28.92	36.66	2.03
16:00	29.1	29.38	39.5	2.22
17:00	30.1	32.41	40.36	2.25

Table-5.2 (b) Inlet Temp, Middle & Outlet Temp. OfETHE (JAN-2022)

- Time & Inlet Temp (Jan-2022)

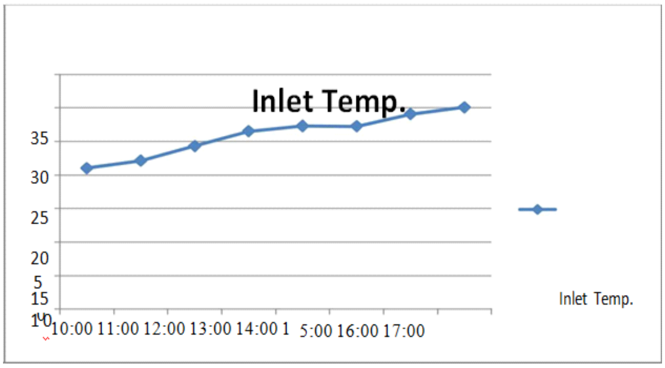


Fig. No. 5.9 Variation of Inlet Temp with Time

- Time & Outlet Temp (Jan-2022)

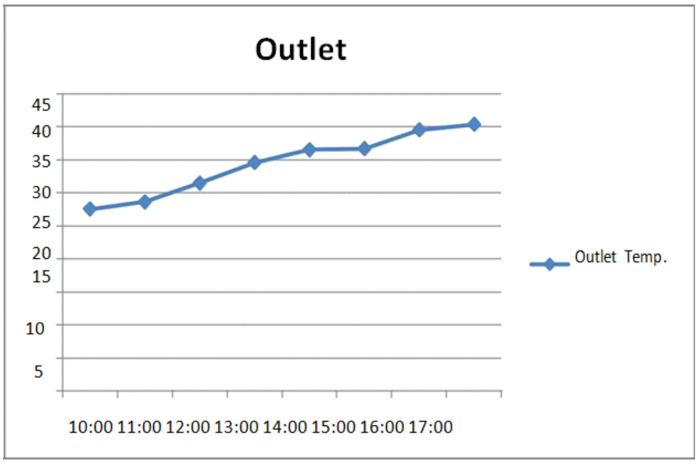


Fig. No. 5.10 Variation of Outlet Temp with Time T

- Time & Cop (Jan-2022)

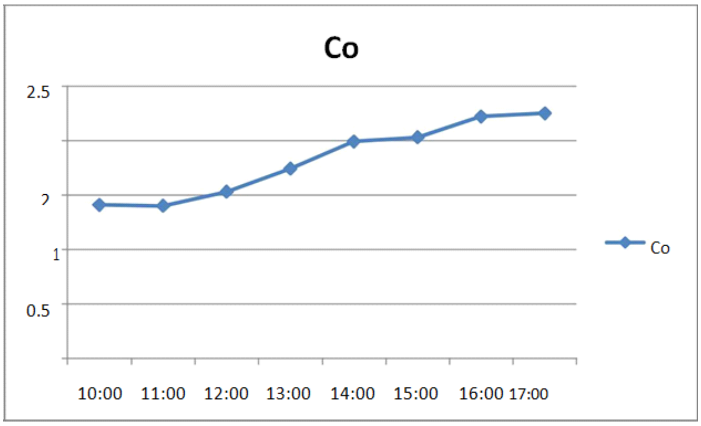


Fig. No. 5.11 Variation of COP with T

- Time, Inlet, Outlet Temp & Cop (Jan-2022)

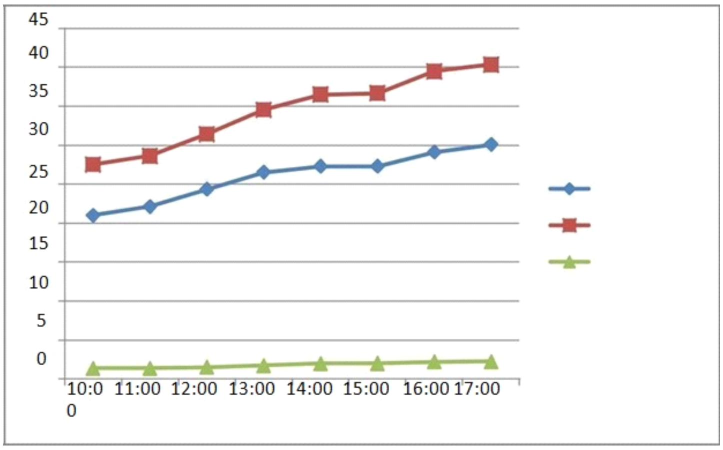


Fig. No. 5.12 Variation of Inlet, Outlet Temp. & COP withTime

5.2(B) HEATING MODEL TEST (COPPER PIPE):

Heating mode test tests were carried out for three Day of Jan.2022 (02, 3&4th) The system was turned on at 10am and operated for 8 hours continuously, till 5 pm that day. Temperature readings were noted at hourly interval. Here also the conditions on the three consecutive days weresimilar and therefore the results combined.

Average Inlet Temp, Middle And Outlet Temp. of ETHE(Jan-2021)				
Time	Ta=Ti	Tmid	To	COP
10:00	21	29.52	30.63	2.08
11:00	22.13	30.54	31.63	2.05
12:00	24.33	3050	32.43	1.75
13:00	26.53	30.76	36.56	2.16
14:00	27.3	32.62	36.44	1.98
15:00	27.27	32.82	36.66	2.03
16:00	26	32..36	37.04	2.39
17:00	25.05	30.04	35.03	2.16

Table-5.2 (d) Inlet Temp, Middle & Outlet Temp. OfETHE (JAN-2021)

Table 5.2(a) shows the measured data, and Table 5.2(b) which is the mean of three test runs. The ambient temperature started at 21oC (10 AM), increasing the highest value 30.30oC at 5 pM. Basic soil temperature at 3 m depth was constant at 24.2oC.

In Copper Pipe Temperature of the air at the outlet varyingfrom 30.63oC to 37.04oC. ETHE was able to raise the ambient air temperature at 10AM To 5 PM from 21.00oC to 25. 05oC.The table also shows the COP values. Themaximum COP Achieved at 4pm i.e. 2.39.

- 5.2(b) Time & Inlet Temp (Jan-2022)

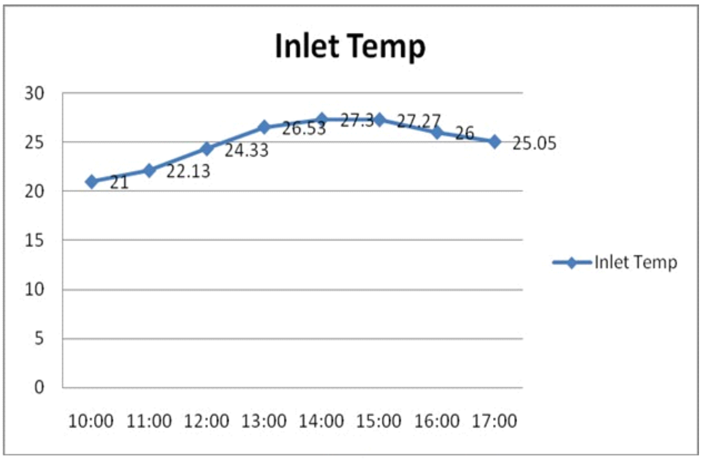


Fig. No. 5.13 Variation of Inlet Temp with Time

- 5.2 (c) Time & Outlet Temp (Jan-2022)

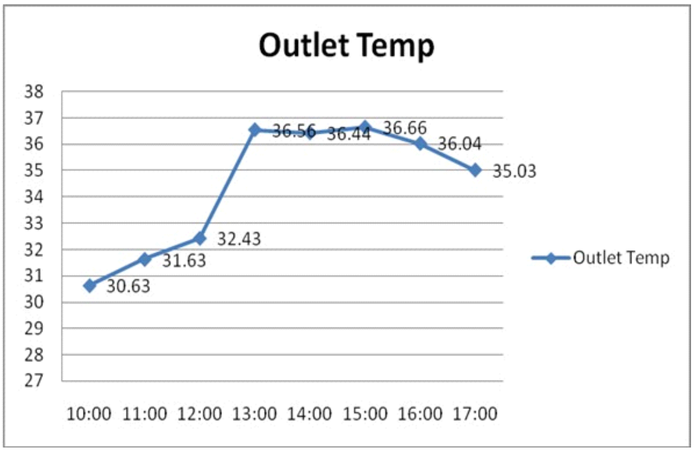


Fig. No. 5.14 Variation of Outlet Temp with Time

- (d) Time & Cop (Jan-2022)

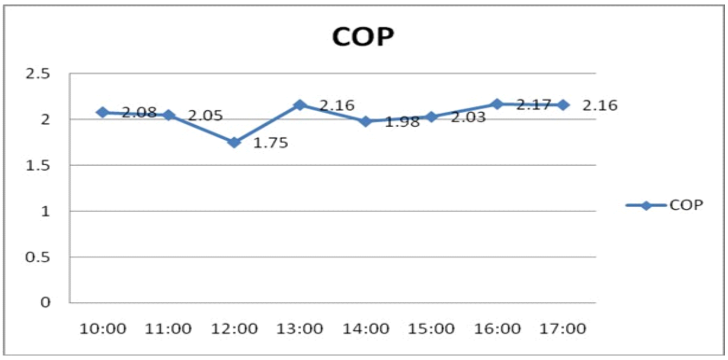


Fig. No. 5.15Variation of COP with Time

2. CONCLUSION

After done the calculation in the previous chapter, we can see that the results are quite encouraging. The results are summarized under the following points:

1) IN GI Pipe For the pipe of 9 m length and 0.05 m diameter, temperature rise of 3.230C-6.10C has been observed for the outlet flow velocity 11m/s
2) IN COPPER Pipe For the pipe of 9 m length and 0.05 m diameter, temperature rise of 8.330C- 10.10C has been observed for the outlet flow velocity 11m/s
3) IN GI Pipe The maximum COP obtained in summer season is 2.817 at time 14:00 and the maximum COP obtained in winter season is 2.25 at time 17:00
4) IN COPPER Pipe The maximum COP obtained in summer Season is 3.68 at time 14:00 and the maximum COP obtained in winter Season is 2.39 at time 17:00 m/s. ow velocity 11m/s
5) IN GI Pipe The COP of the system varies from 0.85 – 2.70 in summer season and 1.41-2.25 in winter season in outlet velocity 11m/s.
6) IN COPPER The COP of the system varies from 1.53 – 3.68 in summer Season and 1.75-2.39 in winter Season in outlet velocity 11
7) 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.
8) 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 andenvironmental variables. The work can aid in designing of such systems with flexibility to choose different types of pipes, different dimensions of pipes, different materialsand 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 ofthe pipe, type of fluid to be used.

FUTURE SCOPE

- The blower with variable running speed should be used.
- Theoretical model should be developed to predict the temperature of soil per meter depthofsoil and affect of moisture content in the soil.
- This system will be tested for different length and different diameter pipe.
- For further study humidity control mechanism should beincorporated for winter and summer season.
- The fluid dynamics studies should be conducted to minimize the flow losses in the pipe and effect of moisture to be studied.

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