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Earth Air Heat Exchanger Performance in Summer Cooling For Various Supply Air Conditions

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ABSTRACT

There is a growing interest in heating and cooling systems based on renewable energy. This is the property of earth ground the below about 2.5 to 3 m, the temperature of ground remains nearly constant throughout the year. This constant temperature is called undisturbed temperature of earth. However, a good visualize the undisturbed ground temperature, for a correct interpretation of the geothermal heat exchanger. The undisturbed temperature is very important yourself, which remains higher than the outside temperature in winter and lower than the outside temperature in summer. The EAHEs are considered as an effective passive heating/cooling medium for buildings. It is basically a series of metallic, plastic or concrete pipes buried underground at a particular depth through which the fresh atmospheric air flows and gets heated in winter and supplied to the building if at sufficiently high temperature and vice versa in summer. Until now, many researchers have conducted a series of studies in the development, modelling and testing of systems of the EAHE. This paper observe on earth air heat exchanger in summer cooling for various supply air conditions in summer climate in LNCT Energy Park Raisen Road Bhopal M.P.

Introduction

The idea of using earth as a heat sink was known in ancient times. In about 3000 B.C., IRANIAN ARCHITECTS used wind towers and underground air tunnels for passive cooling [1, 2]. Underground air tunnels (UAT) systems, nowadays also known as Earth to Air Heat Exchangers have been in use for years in Developed countries due to their higher energy utilization efficiencies compared to the conventional heating and cooling system. Earth -air heat exchanger is a system of work that the thermal inertia of the earth for heating / cooling use of buildings, offices, residential, industrial,etc. or another word of earth-air heat exchangers Are effective as emphatic substitute for these rated can be used for heating / cooling the building. This is a principally a series of metallic, plastic or concrete pipes immerse below the earth at a particular depth. Energy savings of great thought is everywhere a special challenge in the desert climate. The climate of the desert can be classified as hot and dry and such a condition exists in a number of areas around the world. In general, most people probably when the temperature is between 20 ° C and 26 ° C and a relative humidity is ranging from 40 to 60%.These conditions are often achieved by the use of air conditioners. Air conditioning is widely used for the comfort of the occupants and the industrial productions. It can be effectively achieved by vapour compression machines, but to minimize due to the depletion of ozone layer and global warming by chlorofluorocarbons and the need for high-grade energy consumption various passive techniques are now introduced a day, such a process is the earth-to-air heat exchanger. An earth- air heat exchanger consist in one or more pipe/tubes below the earth about 2.5 to 3 m in order to cool in summer climates and pre-heat in winter climates air to be supplied in a building. The physical phenomena of earth-air heat exchanger is simple the ground temperature or undisturbed temperature of earth generally higher than the outdoor air temperature in winter and lower in summer, so it makes the use of the earth suitable as warm or cold sink respectively. Both of the above uses of earth air heat exchanger can pass to reduction in energy consumption. Several researchers have described the earth-to-air heat exchangers (EAHE) coupled with buildings as an effective passive energy source for building space conditioning. An earth- to-air heat exchanger system suitably meets heating and cooling energy loads of a building. Its performance is based upon the seasonally varying inlet temperature, and out let temperature which further depends on the ground temperature or undisturbed temperature. The performance of the EAHE system depends on the temperature and humidity distribution in the soil, as well as to the surface conditions.

Working Principal of Earth Tube Heat Exchanger

The principle of the basic inertia for heating and cooling using is not a new concept, but a modified concept that goes back to the ancients. This technology has been used throughout history by the ancient Greeks and Persians in the pre-Christian era until recent history (Santamouris and Asimakopoulos, 1996) [3,4,5]. For instance the Italians in the middle Ages used caves called colvoli, to precool /preheat the air before it entered the building. The system, which is currently used, consists of a matrix of on buried pipelines, through the air by a fan / blower. In summer, the supply of ambient air through the tubes to the buildings is due to the fact, cooled, that the undisturbed temperature is lower around the heat exchanger than the ambient temperature. Same as opposite rule of winter climates, the undisturbed temperature is the greater than the ambient temperature and the air gets preheated.

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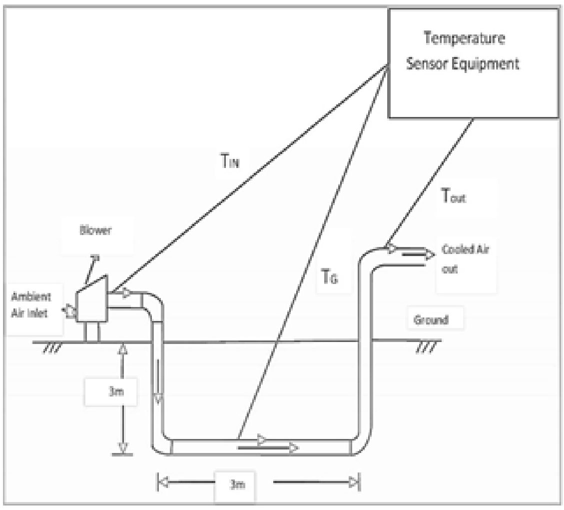

Fig 1. Earth Air Heat Exchanger.

Types of Earth Tube Heat Exchanger

There are two types of heat exchanger

1. Closed type Earth tube heat exchanger
2. Open type Earth tube heat exchanger

Closed System

Air from inside the home or structure is a U-shaped loop of typically 30 to 150 m (100 to 500 ft) blown from tubes, where it will be hosted near ground temperature before over in the house or the structure distribute air ducts returns. The closed loop system may be more effective (while the air temperature extremes) as an open system, as it cools and cools again, the same air. In this case, heat exchangers are arranged underground, either vertical or oblique position, and a heat transfer medium in the heat exchanger circulates in horizontal to transfer the heat from the soil to a heat pump, or vice versa.

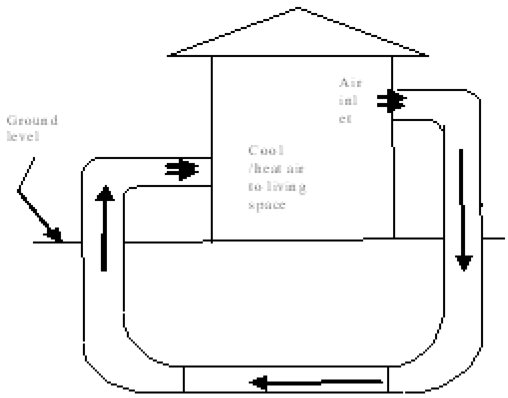

Fig 2. Closed System.

- Increases efficiency.
- Reduce moisture problems inside tube condenses.
- Domestic air circulates through the heat exchanger Earth air tube.

Open System

Outside air is drawn from a filtered air inlet. The cooling tubes are typically 30 m (100 ft) long straight pipes in the home. An open system with energy recovery ventilation is combined, can be almost as effective (80-95%) as a closed loop and ensures that fresh air enters, is filtered and tempered. In open systems environment air passes through pipes buried in the ground for preheating or pre-cooling and then the air is heated or cooled by a conventional air conditioning unit before entering the building.

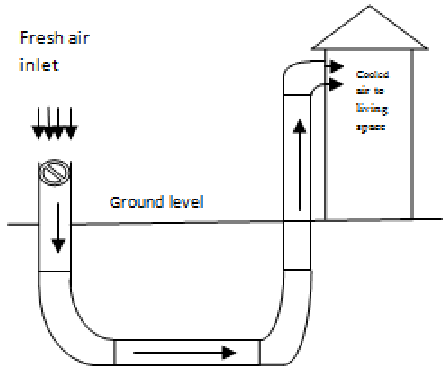

Fig 3. Open System

- Outside air is drawn into the tubes and air handling units (AHUs) or directly supplied to the inside of the building.
- Hopefully ventilation ensures under cooling or the building interior heating.
- Improves indoor air quality (IAQ).

Combination System

This can be constructed with dampers, either closed or open to allow operation, depending on the fresh air ventilation requirements. Such a design could also drag in a closed loop, a lot of fresh air, when a drop in air pressure created by a solar chimney dryer, fireplace, kitchen or bathroom exhausts vents. It is better to draw outside air into the air as in the filtered passive cooling pipe.

Hybrid System

Earth air tube heat exchanger system coupled with another heating / cooling system that can air conditioning, evaporative cooling system or solar air heating. Hybrid systems are being preferred over unitary system due to higher efficiency.

Literature Review

The heat transfer to and from Earth tube heat exchanger system has been the subject of many theoretical and experimental analysis. A observe of previous research published by many authors by an idea of how it works.

S. Barakat. [6] Developed an Enhancement of gas turbine power output using earth to air heat exchanger (EAHE) cooling system. In this work, there will be new intake air introduced refrigeration system for gas turbine use EAHE system of passive cooling, for the application of this system, firstly it should be examined by predicting the underground soil temperature at different depths along the year, the soil behaviour and determines the optimal depth for high performance and low economic cost.

Longer earth tube and deep with a smaller diameter and lower air intake velocity lead to a reduction of the air outlet temperature given.

Suresh Kumar Soni, [7] Developed the Ground coupled heat exchangers. The use of ground coupled heat exchanger (GCHE) systems is increasing worldwide. They are mainly used for air Conditioning, water heating, agricultural drying, bathing, swimming, etc. They used to reduce the summer heat load and winter cooling load. GCHE systems provide excellent scope to save significant amount of primary energy and thus to mitigate the impact on the environment by reducing emissions. EAHE and GSHP systems the attention of researchers and designers, as they are efficient, economical, environmentally friendly and renewable in nature.

Akshay khot, [8] Developed an Analysis of various designing parameters for earth air tunnel heat exchanger system, EATHE evaporating cooling hybrid system can be used for better result with increasing tube length, decreasing tube diameter and decreasing mass flow of air flowing inside buried pipe and increasing depth of soil up to 4 m of power EATHE will be better used in the summer.

Suresh Kumar Soni [9] Developed the Hybrid ground coupled heat exchanger systems for space heating/cooling applications. Hybrid GCHE systems with uniform system preferred because of greater efficiency. Review of hybrid GCHE systems concluded that hybrid of EAHE with evaporative cooler could increase cooling effect by 69% and reduce length of buried pipe up to 93.5%. Hybrid system could reduce significant amount of power consumption. DX-GSHP with conventional air conditioning system could reduce power consumption by 15.5%.

Manoj kumar Dubey [10] developed an Earth Air Heat Exchanger in Parallel Connection. The experimental results shows the temperature difference between the inlet section and outlet section of the pipe at a depth of 1.5m in a parallel connection, and finds the maximum temperature difference is 8.6 to 4.18 ° C at a velocity of varies from 4.1 to 11.6 m/s. Cop in the parallel connection and its value is varies from 5.7 to 2.6 for increase in velocity from 4.16 to 11.2 m/s. ETHE systems therefore do not cause any toxic emissions and harmful for the environment and ETHE based systems for cooling need no water - a feature useful in dry areas like Kutch. It is this property that motivates our work to ETHE development.

Bansal V, [11,12] Developed a Performance analysis of earth– pipe–air heat exchanger for summer cooling and winter heating. an experimental setup of EAHE system in Ajmer in India, which had two horizontal cylindrical tubes of 0.15 m internal diameter, 23.42m buried length of each consisting of polyvinyl chloride (PVC) and Steel, at a depth of 2.7 m buried in flat land with dry soil. It has been found from the experiment that the power of each System was not affected by the material of the buried pipe for winter and summer cooling /heating. Temperature dropped more initial length of underground pipe. Then cost and durability would be the deciding factor for selection of material of pipe. It was suggested that plastic pipes extreme care when filling methods require the pipes against mechanical damage to avoid that as galvanized steel tubes come from mechanical injury, but raise the cost by 25-30% of project. It was also found that it was a fair agreement between the simulated and experimental results.

Mihalakakou G, [13] Developed the influence of different ground covers on the heating potential of earth-to-air heat exchangers. To the buried pipes radius increase leads to a reduction in the convective heat transfer coefficient. This leads to a lower air temperature at the tube exit and thus reducing the heating capacity of the system. It also reduces exhaust temperature is associated with an increased pipe surface as the pipe radius increases and pipe length causes an increase in buried pipelines length increase exhaust temperature, which means that the potential systems can also increase heat output and typical diameters are 10 cm to 30 cm, can be but as large as 1m for commercial buildings.

Badescu V, [14] Developed the Simple and accurate model for the ground heat exchanger of a passive house. the material has little effect on the summer and winter performance.

Zimmermann M, [15] Developed the ground coupled air system, low energy cooling-technology selection. When parallel tube systems are used tubes are approximately 1 meter from each other to minimize, thermal interaction to be held. A greater distance was not to bring any additional benefits found.

Ascione F, [16] Developed the earth to air heat exchangers for Italian climates. It is closely related to building use.. The most convenient solution for office buildings is EAHE the day to use throughout. Thus, a 15-hour day is the best solution, and should be the system of the past, when the outdoor temperature enters a particular area (for example15-22 1C); The system can be controlled by mass temperature or outdoor air temperature.

Ozger L, [17] Developed the experimental and analytical analysis of earth to air heat exchanger (EAHE) systems. EAHE systems include buried pipelines in various combinations, in open-loop and closed-loop. The air is drawn through buried pipes blown at the input or output installed using a properly sized blower fan.

Ghosal MK, [18] Developed the Modelling and comparative thermal performance of ground air collector and earth heat exchanger for heating of green house. Tested and developed a model to investigate the thermal performance of a EAHE system, coupled with a green house at the Indian Institute of Technology, New Delhi, India. It was found that green house air temperature in winter increased with reducing pipe diameter and mass flow rate of air, pipe length and depth of the buried pipe increase up to 4 m. A fair agreement was between the measured values and predicted values of the green house air temperature with respect to the statistical analysis is root mean square of percentage deviation and correlation coefficient found. **Popiel [19]** present the temperature distributions measured in the ground for the period between summers 1999 to spring 2001. The investigation was carried out in Poland. From the point of view of the temperature distribution they distinguish three ground zones. Reach surfaces zone to a depth of about 1 m, when the ground temperature is very sensitive to short term changes in the weather conditions. Shallow zone from the depth of about 1 to 8 m (for the dry light soil) or 20 m (for wet heavy sandy soils) extends, where the ground temperature is almost constant and close to the average annual air temperature; in this zone depend soil temperature distributions mainly due to the seasonal cycle weather conditions and Depth Zone below the depth of the shallow zone where the ground temperature is practically constant (and very slowly with increasing depth according to the geothermal gradient.

Discussions

The experiments were carried to evaluate the performance of Earth Air Tube Heat Exchanger for the following design parameters (Fig 1. U shaped EATHEs). Depth (D') = 3m, Tube Length (L) = 9m, Tube Diameter (d) = 0.05m, Air velocity (V) = 11m/s. Power Input = 125W. Formula used,

$Qc = m\, Cp\, (T_{inlet} – T_{outlet})$

$COP = mCp\, (T_{inlet} – T_{outlet}) / \text{Power Input}$

Since the temperature at the earth's surface is always lower than the atmospheric temperature during the summer season. In this dissertation work a particular design of earth tube heat exchanger established at LNCT BHOPAL Energy Park has been observed performance during summer season. The investigations on air cooling through EAHEs were performed and the temperatures of inlet and outlet air from the heat exchanger and earth pipe were measured. On the basis of the temperatures obtained COP and performance of the heat exchanger is evaluated. For the evaluation of the performance the earth air heat exchanger was operated for eight hours a five days 10, 11, 12, 13, 14 & 15th of March- 2016 and April 2016 month at the time 10AM to17PM. The tube air temperature at the inlet, ground and outlet, were noted at the interval of one hour. The temperature of these all days was very closely. The duration of temperatures calculation into consideration for the month of March & April.

Set up Box of Earth Air Tube Heat Exchanger

Fig 4. Experimental set up (LNCT Energy Park)

Fig 5. Taking Temperature Reading from Temperature Sensor

Case 1 March

- **Time Vs inlet temperature, intermediate temperature, outlet temperature and difference of inlet and outlet temperature in March**

Date: 10/03/2016

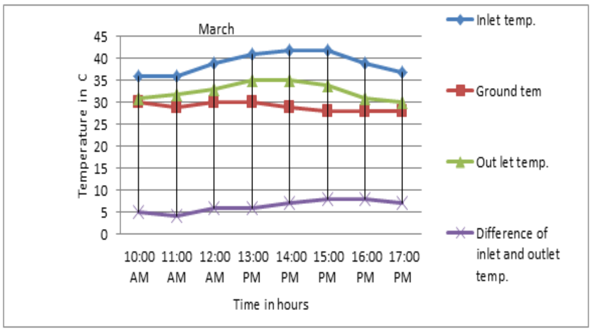

Fig 6. Variation of inlet temp, Ground Temp, Outlet Temp. and difference of inlet & outlet Temp. W.r.to Time

- **Time Vs inlet temperature, intermediate temperature, outlet temperature and difference of inlet and outlet temperature in March**

Date: 11/03/2016

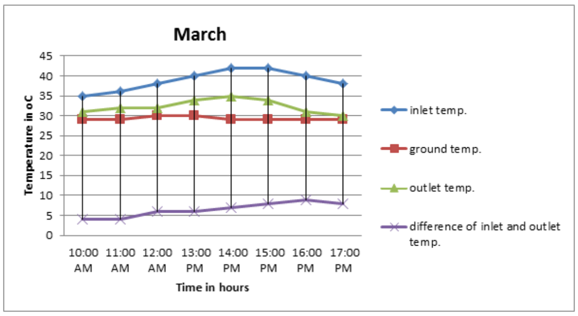

Fig 7. Variation of inlet temp. Ground Temp. Outlet Temp. and difference of inlet & outlet temp. W.r.to Time

- **Time Vs inlet temperature, intermediate temperature, outlet temperature and difference of inlet and outlet temperature in March**

Date: 12/03/2016

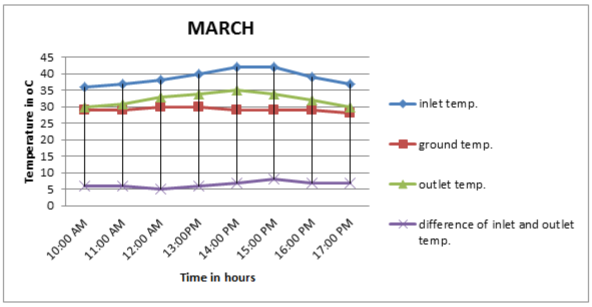

Fig 8. Variation of inlet temp. Ground Temp. Outlet Temp. and difference of inlet & outlet temp. W.r.to Time

- **Time Vs inlet temperature, intermediate temperature, outlet temperature and difference of inlet and outlet temperature in March**

Date: 13/03/2016

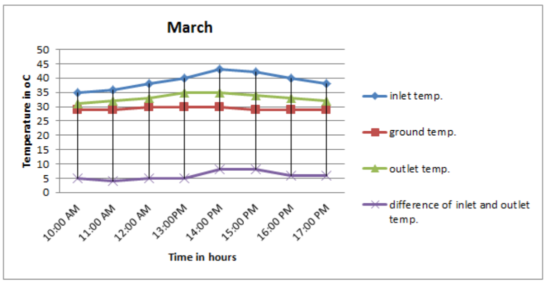

Fig 9. Variation of inlet temp. Ground Temp. Outlet Temp. and difference of inlet & outlet temp. W.r.to Time

- **Time Vs inlet temperature, intermediate temperature, outlet temperature and difference of inlet and outlet temperature in March**

Date: 14/03/2016

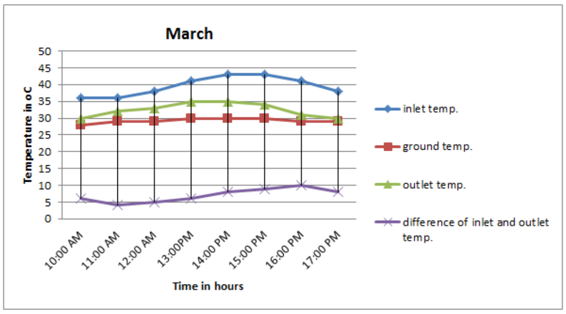

Fig 10. Variation of inlet temp. Ground Temp. Outlet Temp. and difference of inlet & outlet temp. W.r.to Time

- **Time Vs COP**

Date: 10/03/2016, 11/032016, 12/03/2016, 13/03/2016 and 14/03/2016

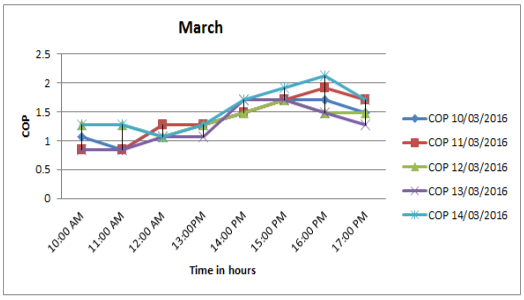

Fig 11. Variation of COP w.r.to Time

- **Time Vs Heat transfer cooling in Watt**

Date: 10/03/2016, 11/03/2016, 12/03/2016, 13/03/2016 and 14/03/2016

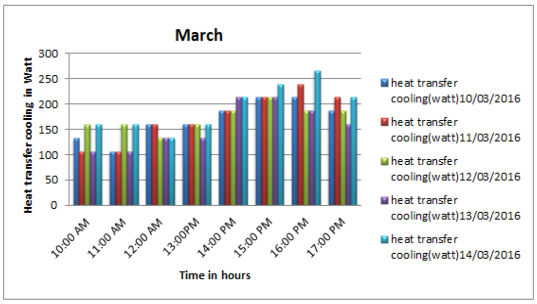

Fig 12. Variation of Heat transfer cooling in (Watt) w.r.to Time

Case 2 April

- **Time Vs inlet temperature, intermediate temperature, outlet temperature and difference of inlet and outlet temperature in April**

Date: 10/04/2016

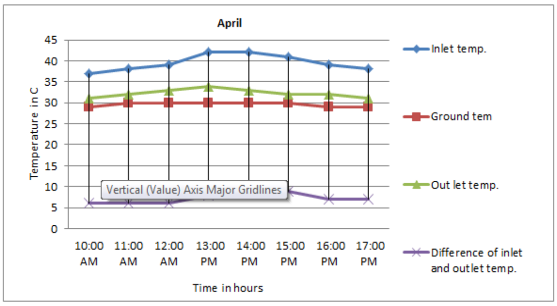

Fig 13. Variation of inlet temp. Ground Temp. Outlet Temp. and difference of inlet & outlet temp.W.r.to Time

- **Time Vs inlet temperature, intermediate temperature, outlet temperature and difference of inlet and outlet temperature in April**

Date: 11/04/2016

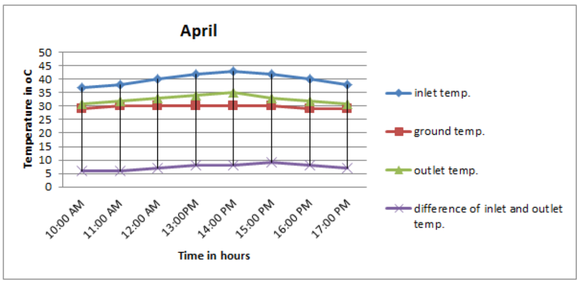

Fig 14.Variation of inlet temp. Ground Temp. Outlet Temp. and difference of inlet & outlet temp. W.r.to Time

- **Time Vs inlet temperature, intermediate temperature, outlet temperature and difference of inlet and outlet temperature in April**

Date: 12/04/2016

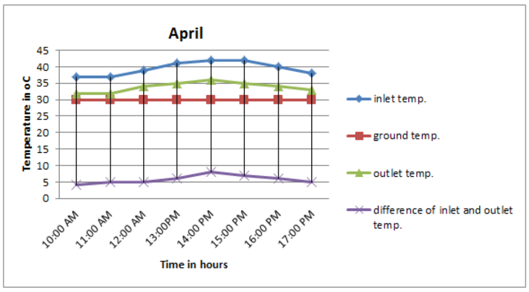

Fig 15. Variation of inlet temp. Ground Temp. Outlet Temp. and difference of inlet & outlet temp. W.r.to Time

- **Time Vs inlet temperature, intermediate temperature, outlet temperature and difference of inlet and outlet temperature in April**

Date: 13/04/2016

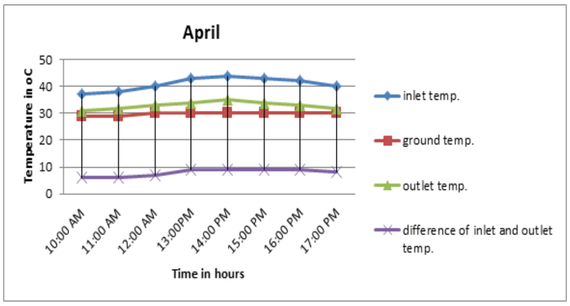

Fig 16. Variation of inlet temp. Ground Temp. Outlet Temp. and difference of inlet & outlet temp. W.r.to Time

- **Time Vs inlet temperature, intermediate temperature, outlet temperature and difference of inlet and outlet temperature in April**

Date: 14/04/2016

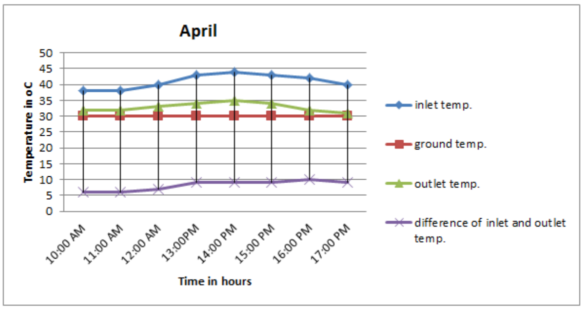

Fig 17. Variation of inlet temp. Ground Temp. Outlet Temp. and difference of inlet & outlet temp. W.r.to Time

- **Time Vs COP**

Date: 10/04/2016, 11/042016, 12/04/2016, 13/04/2016 and 14/04/2016

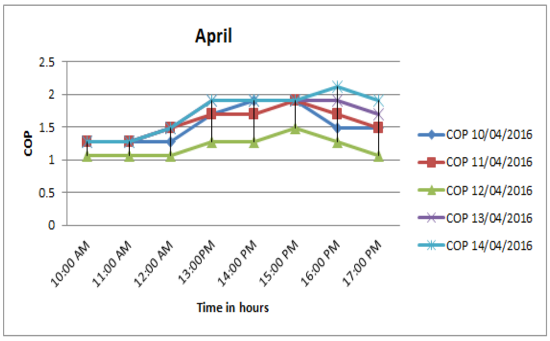

Fig 18. Variation of COP w.r.to Time

- **Time Vs Heat transfer cooling in Watt**

Date: 10/04/2016, 11/04/2016, 12/04/2016, 13/04/2016 and 14/04/2016

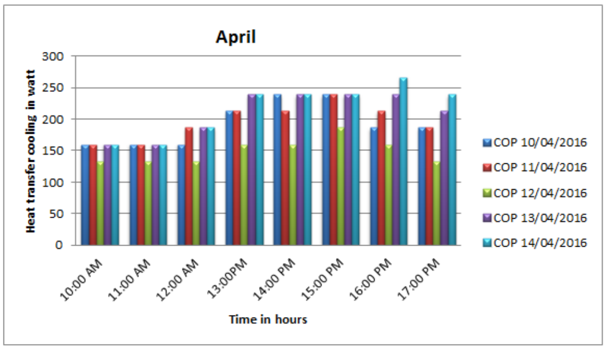

Fig 19. Variation of Heat transfer Cooling in (Watt) w.r.to Time

Conclusion

The performance of earth air heat exchanger system was investigated experimentally.

The experimentally results indicates the temperature difference of the inlet and outlet section varies 4 to 10 °C in March and 5 to 10 °C in April and COP varies from 0.85 to 2.12 in March and 1.28 to 2.12 in April. The maximum COP obtained in summer season is 2.12 at 4:00 PM in the month of March and April. The maximum heat transfer obtained in summer season is 265.65 watt and minimum heat transfer obtained in summer season is 106.38 watt. Ground temperature is almost uniformly in March and April. The blower speed that is velocity of the air flow that is 11 m/s was also optimize and it was observed that of the blower velocity is increased and the length of the pipe is less, then the temperature difference of inlet and outlet is observed as very small.The design of earth–air heat exchanger mainly depends on the heating/cooling load requirement of a building to be conditioned. The diameter of pipe, pipe length, and number of pipes are the main parameters to be determined. Smaller diameter gives better thermal performance and increase diameter results in reduction in air speed and heat transfer. With an increase in length of pipe, both pressure drop and thermal performance increase hence increase fan energy and after certain length no significant heat transfer occurs, hence optimize length so economic and design factors need to balanced to find best performance at low cost .A longer pipe of smaller diameter buried at a greater depth and having lower air flow velocity results in an increase in performance of the EAHE system. That the result of this finding may be used for designing as a tool for systems depending upon the requirement and environment variables.

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