ISSN: 2278-0181
ICRTME - 2016 Conference Proceedings

A Review on Earth-Air Heat Exchanger

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Abstract **-The demands of cooling energy & the thermal comfort requirements are rapidly increasing day by day due to global warming effect. The temperature of earth at a certain depth about 1.5 m to 3 m the temperature of ground remains nearly same throughout the year. This temperature remains more than the outside temperature in winter season and lowers than the outside temperature in summer season. The earth air heat exchanger is the possible approach to reduction of heat loss and for the thermal comfort improvement. Earth air heat exchanger or earth tube heat exchanger is a device used to produce heating effects in winter and cooling effects in summer using the ground or soil as a source or sink. 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 air heat exchanger can full fill in both purposes heating in winter and cooling in summer. This paper focus on the effects of various parameters on performance of Earth air heat exchanger and result shows that the energy consumption is reduced by implementation of Earth air heat exchanger.**

Keywords – Earth-air heat exchanger; Ambient air; Buried pipes.

I. INTRODUCTION

It is found It is found that the soil at some depth from earth surface has a property to remain cold during summer and relatively hotter during winter days from the atmospheric temperature. Due to limited sources of energy, it is very essential to find out the another alternative sources of energy to save the conventional fuels available in nature to save energy of universe. The energy consumption of buildings for heating and cooling purpose has significantly increased during the decades. Energy saving is the major concern everywhere, particularly challenge in desert climates. The comfort conditions for human being are temperature between 200 to 260 and relative humidity in between 40% to 60% . This can be achieved by conditioning air[4]. The system used in now a days, air is passed through a buried pipe by fan. In summer the supply air to the building is cooled due to the fact that the ground temperature around the heat exchanger is lower than the ambient temperature. During winter, when the ambient temperature is lower than the ground temperature the process is reversed and the air gets preheated.

The earth air heat exchangers are considered as an effective replacement for heating or cooling of buildings. This is basically metallic, plastic or concrete pipes buried underground at a particular depth. Through pipes the fresh atmospheric air pass with the help of blower. According to the temperature difference the heat transfer takes place between soil and air in pipes. The efficient design of the system is necessary to ensure good performance. In that accordance the cross section area and type of cross section of pipe, velocity of air and nature of soil plays key role in efficiency of system. This uses green and clean energy in order to minimize pollution and to minimize conventional energy consumption.There are two major types of Earth Air Heat Exchangers system exist

A. Open type earth tube heat exchanger

B. Closed type earth tube heat exchanger

A. Open System

In open system Fig.1 shows the ambient air passes through tubes 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.

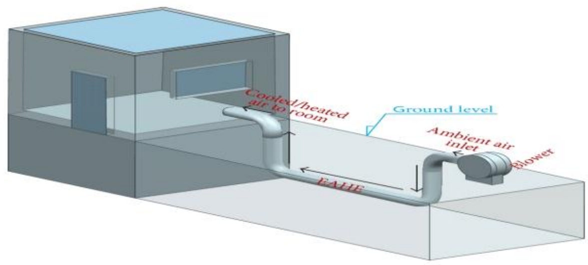

Fig. 1: Open Loop System

B. Closed System

In Fig.2 the heat exchangers are located underground, either in horizontal, vertical position, and a heat carrier medium is circulated within the heat exchanger, transferring the heat from the ground to air or vice versa.

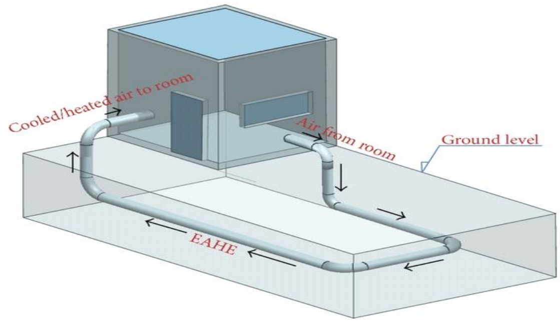

Fig. 2: Closed Loop System

EAHE can be used as alternative for the conventional air conditioning systems. EAHE-evaporating cooling hybrid systems can be used in summer for better results. More the thermal conductivity of soil better is the thermal performance of EAHE .With increasing pipe length, decreasing pipe diameter, decreasing mass flow rate of flowing air inside buried pipe and increasing depth of ground up to 1.5 to 2 m performance of EAHE becomes better.[1]

II. LITERATURE REVIEW

Rohit Misra, Vikas Bansal,Ghanshyam Das Agrawal et al. [2013] has expressed that with increase in length of pipe, the outlet air temperature from EAHE decreases. The decrease in air temperature was sharp for the first 10 meters length of pipe and it became moderate afterwards. So, increasing the length of pipe more than 20- 30m did not cause any significant rise in performance and improvements began to stabilize, indicated these values could be optimal design values for hot and dry climatic conditions of Bhopal. It was observed that with increase in pipe diameter, the outlet air temperature of EAHE increases because the convective heat transfer coefficient at inner surface of pipe as well as overall heat transfer coefficient at earth- pipe interface decreases at higher pipe diameters. With increase in depth of pipe burial, outlet air temperature of EAHE system decreases. So, pipes of EAHE system should be installed as deeply as possible but it increases excavation cost. So, it is advised to keep depth of pipe burial about 2m in order to limit the initial/installation cost of EAHE system. The outlet air temperature of EAHE system increases with increase in air flow velocity. This is because of the fact that as the air flow velocity is increased, the time to which air remains in contact with ground is reduced. The performance of EAHE cannot be increased only by decreasing the air flow velocity because the cooling capacity of EAHE system depends both on air flow velocity and temperature difference. So, both air flow velocity and temperature difference should be considered at the same time.[5]

Capozza A, De Carli M st al. [2012]has expressed that the heat transfer to and from Earth tube heat exchanger system has been the subject of many theoretical and experimental investigations. By having a review on previous research papers published by many authors we can have an idea on how it works. A one-dimensional numerical model to check the performance of EAHE installed at different depths. It was concluded that EAHE systems alone are not sufficient to create thermal comfort, but can be used to reduce the energy demand in buildings in South Algeria, if used in combination with conventional air conditioning system. a simplified analytical model to study year around effectiveness of an EAHE coupled greenhouse located in New Delhi, India. They found the temperature of greenhouse air on average 6- 7 °C more in winter and 3-4 °C less in summer than the same greenhouse when operating without EAHE. A developed thermal model for heating of greenhouse by using different combinations of inner thermal curtain, an earth air heat exchanger, and geothermal heating. the performance analysis of EAHE for summer cooling in Jaipur, India. They discussed 23.42 m long EAHE at cooling mode in the range of 8.0-12.7 °C and 2-5 m/s flow rate for steel and PVC pipes. They showed performance of system is not significantly affected by the material of buried pipe instead it is greatly affected by the velocity of air fluid. They observed COP variation 1.9- 2.9 for increasing the velocity 2-5 m/s.[6]

N.K. Bansal, M.S.Sodha, S.P.et.al.[2012] has expressed that EATHE can be used as substitute for the conventional air conditioning systems EATHE-evaporating cooling hybrid systems can be used in summer for better results. More the thermal conductivity of soil better is the thermal performance of EAHE With increasing pipe length, decreasing pipe diameter, decreasing mass flow rate of flowing air inside buried pipe and increasing depth of ground up to 4 m performance of EAHE becomes better[7]

According to Kim S K, Bae G O, Lee K et.al[2010] if the length of the pipe is so small and the blower is high voltage then the system is useless because the temperature difference between inlet and out let is very Less The material of pipe is not affected in the output result. If cooling or heating rate is more achieve, then the length of pipe kept at least 100 m and blower some around 400 W [8]

Bisoniya TS, Kumar A, Baredar P et.al [2014] has expressed that the earth–air heat exchanger is a promising technique which can effectively be used to preheat the air in winter and vice versa in summer. Many researchers have developed EAHE design equations and procedures. For a complete analysis of the EAHE system, For the initial design of an EAHE system, the use of basic heat transfer equations is more suitable to determine the geometrical dimensions of the system. In this paper, the author has developed a one-dimensional model of the EAHE system. The method to calculate the EUT and more recently developed correlations for friction factor and Nusselt number are used to ensure higher accuracy in the calculation of heat transfer. The value of EUT for Bhopal (Central India) was calculated as 25.2 °C. It was observed that Nusselt number increases with increase in Reynolds number. The design of earth–air heat exchanger mainly depends on the heating/cooling load requirement of a building to be conditioned. After calculation of heating/cooling load, the design of the earth–air heat exchanger only depends on the geometrical constraints and cost analysis. The diameter of pipe, pipe length, and number of pipes are the main parameters to be determined. With an increase in length of pipe, both pressure drop and thermal performance increase. 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.[9]

Thankur, A., Sharma et.al [2015] has expressed that the finned mild steel pipe of 1.2m and diameter 0.0889m inside the earth produced a temperature fall till 3°C for various daily temperatures. For higher inlet temperature and the outlet temperature difference recorded is mostly from 2- 3°C. The COP of the heat exchanger ranges from 0.928 – 2.785 for temperature difference of 1°C - 3°C respectively. Higher COP can be obtained when temperature difference is greater and this can be achieved by using longer pipe for more heat transfer. With a pipe of 1.2m the decrease in temperature is recorded mostly by 1-3°C. For a longer pipe length at this depth 5 ft the temperature of air will decrease significantly since the air will have longer time to flow through the pipe where convective heat transfer will occur for longer time in the tunnel which will produce greater temperature difference and larger COP.[10]

III. METHODOLOGY

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 setup diagram of EAHE is shows in Fig. 3. It has one horizontal pipe of 100 mm inner diameter with total length of 10 m. Three pipes one of 5m length& other two of 2 m are connected made up of PVC material pipes and buried at a depth of 2 m in a flat land with dry soil .Ambient air sucked through the pipe by means of a centrifugal blower by a 2 phase, 0.25 HP, 230 V and 2800 rpm motor. The blower is used to suck the hot ambient air through the pipelines and delivered the cool air for required place in summer climate and hot air required place in winter.

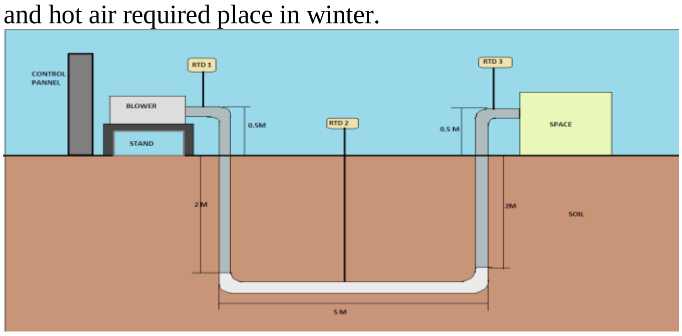

Fig.3: Setup Diagram of EAHE

IV. DESIGN STAGE

Assumptions:

- The surface temperature of the ground is defined as equal to the ambient air temperature, which equals the inlet air temperature.
- EUT can be approximated to the annual average temperature of the location
- 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 resistanceof pipe material is negligible.
- The temperature on the surface of the pipe is uniform in the axial direction

Design procedure:

i. Mass flow rate of air

The mass flow rate of air is an important parameter, and it must be known by the designer so that the selection of size and number of pipes can be initiated. There is no unique value of size and number of pipes which can meet the EAHE performance. So, the designer has to consider the best combination of the EAHE performance and pumping power required to ensure mass flow rate of air.

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

For the designer, these parameters have to be determined in such a way that the boundary conditions and the heat exchanger performance are met.

ii. Earth's undisturbed temperature

The earth's undisturbed temperature is an important parameter in designing an EAHE system. Assuming homogeneous soil of constant thermal diffusivity, the temperature at any depth z and time t can be estimated by the following expression

$$T_{z,t} = T_m - A_s exp\left[-z\left(\frac{\pi}{365\alpha_s}\right)^{\frac{1}{2}}\right] \cos\left\{\frac{2\pi}{365}\left[t - t_o - \frac{z}{2}\left(\frac{365}{\pi\alpha_s}\right)^{\frac{1}{2}}\right]\right\}$$

It is very difficult to calculate accurately the value of earth's undisturbed temperature because the soil parameters are often unknown. Additionally, it is defined for mean soil properties. Hence, earth's undisturbed temperature is a hypothetical value which can be assumed as equal to the annual average soil surface temperature of a particular locality. The soil surface temperature is assumed equal to the ambient air temperature

iii. Methods

If the dimensions of the EAHE system are known, calculation of the heat transfer rate can be done either by using the log mean temperature difference (LMTD) method or the ε–number of transfer units (NTU) method. In this paper the ε–NTU method is used. The outlet temperature of air was determined by using effectiveness of EAHE (ε) which is a function of number of transfer units (NTU).

iv. Heat exchanger effectiveness and NTU

In the earth–air heat exchanger, the medium used for transportation of heat is air only. The heat is released or absorbed by the air flows through the pipe walls by convection and from pipe walls to the surrounding soil and vice versa by conduction. If the contact of the pipe wall with the earth is assumed to be perfect and the conductivity of the soil is taken to be very high compared to the surface resistance, then the wall temperature at the inside of the pipe can be assumed to be constant. The expression of NTU depends on different types of flow configurations of the EAHE system. The total heat transferred to the air when flowing through a buried pipe is given by:

$$Q_h = \dot{m} C_p \left(T_{out} - T_{in}\right)$$

Due to convection between the wall and the air, the transferred heat can also be given by:

$$Q_h = hA\Delta T_{lm}$$

The logarithmic average temperature difference (ΔT lm) is given by (T EUT = T wall):

$$\Delta T_{lm} = \frac{T_{in} - T_{out}}{\ln\left[\frac{(T_{in} - T_{wall})}{(T_{out} - T_{wall})}\right]}$$

The temperature of air at the outlet of the EAHE pipe can be obtained in an exponential form as a function of the wall temperature and inlet air temperature

$$T_{out} = T_{wall} + \left(T_{in} - T_{wall}\right) e^{-\left({hA}/{\dot{m}C_p}\right)}$$

If a pipe of infinite length (A = ∞) is used, the air will be heated or cooled to the wall temperature. The effectiveness (ε) of EAHE for winter heating application can thus be defined as:

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

The non-dimensional group is called the number of transfer units (NTU):

$$\mathrm{NTU} = \frac{hA}{\dot{m}C_p}$$

which gives

$$\varepsilon = 1 - e^{-\mathrm{NTU}}$$

The effectiveness of earth–air heat exchanger is determined by the dimensionless group NTU. The variation in earth–air heat exchanger effectiveness as a function of number of transfer units .

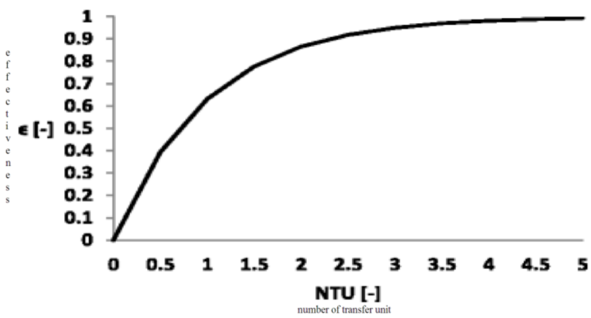

Fig.4: Earth–Air Heat Exchanger Effectiveness As A Function Of Number Of Transfer Units.

It was observed in Fig. 4 that with increase in value of NTU, the effectiveness also increases but the curve rapidly flattens. The relative gain in effectiveness is very small after the value of NTU becomes more than 3. There are a number of ways to construct an earth–air heat exchanger to obtain a given NTU and thus a desired effectiveness.

The influence of the design parameters on NTU can be studied in terms of heat transfer and pressure drop. The NTU consists of three parameters, namely, convective heat transfer coefficient (h), internal surface area of pipe (A) and mass flow rate of air (ṁ) which can vary.

The internal surface area of the pipe is a function of diameter, D, and length of EAHE pipe, L, both:

$$A = \pi DL$$

The convective heat transfer coefficient inside the pipe is defined by:

$$h = \frac{N_u K}{D}$$

where K is the thermal conductivity (W/m-K).

The hydraulic diameter for a circular tube is simply the diameter of the tube. Therefore, it is reasonable to assume that the air flows are mostly fully developed in the EAHEs of such sizes and to adapt the corresponding empirical correlations to calculate the convection heat transfer coefficient (CHTC).. The variation of Nusselt number with respect to Reynold's number for a typical design of conventional EAHE was drawn using all eight correlations to calculate the CHTC, and very large differences were observed among the results of the eight correlations. This may be due to different experimental conditions, which were adopted to derive the correlations, for example, the surface roughness of the experimental ducts. The large discrepancies indicate that a suitable correlation has to be selected if one uses any of the existing models to simulate the performance of an EAHE system.

$$N_u = \frac{f/8\,(R_e - 1000)\,P_r}{1 + 12.7\sqrt{(f/8)}\left(P_r^{2/3} - 1\right)}$$

(For turbulent flow in tubes with smooth internal surface)

f is the friction factor for smooth pipes

$$f = (1.82 \log R_e - 1.64)^{-2}$$

If $2300 \le R\,e < 5 \times 106$ and $0.5 < P\,r < 106$

The Reynolds number is related to the average air velocity and diameter:

$$R_e = \frac{\rho v_a D}{\mu}$$

The Prandtl number is given by:

$$P_r = \frac{\mu c_p}{K}$$

VI . DISCUSSION EFFECTS OF VARIOUS PARAMETERS ON ETHE

i. *Effect of Material*

Initially steel pipes were used for the construction of EAHE but then experiments were conducted for different materials. It is observed that PVC material also give the similar performance hence use cheaper material like PVC instead also there life is more. Though steel has higher conductivity than that of PVC yet the variation in temperature of the air at the outlet of pipe between steel and PVC is very small. Therefore, it can be concluded that in EAHE system, convective heat transfer plays a more important role than conductive heat transfer.

ii. *Effect of Velocity of Air inside Pipe*

The effect of velocity of air inside pipe is shown in Fig. 5. 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

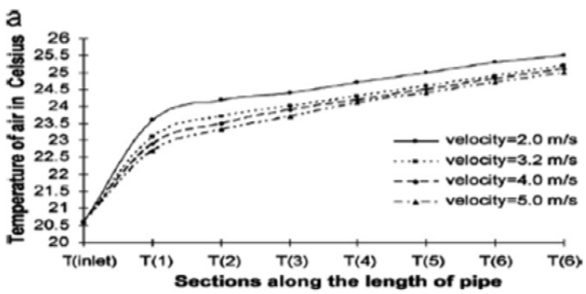

Fig.5: Effect of Velocity of Air inside Pipe

iii. *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. 6.

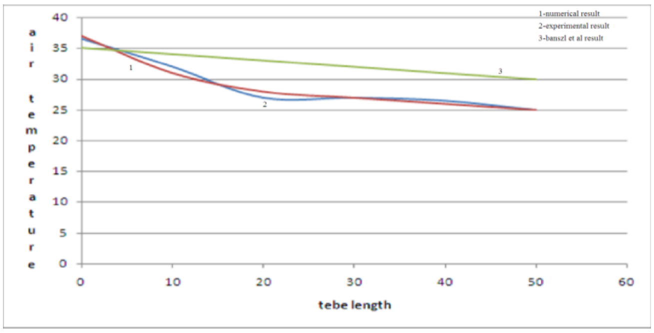

Fig.6: Effect of Tube Length

iv. *Effect of Tube Depth*

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. 7 it is concluded that after a depth of 1.5 meters this temperature becomes stable so the depth taken should be more than 3.5 meters depth is also not justifiable

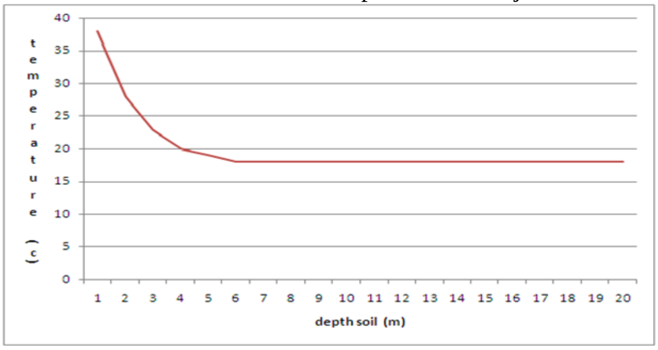

Fig .7: Effect of Tube Depth

v. *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. 8, 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.

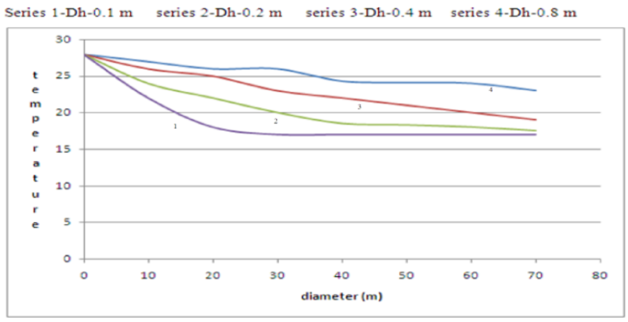

Fig.8: Effect of Tube Diameter

VII. CONCLUSION

More velocity of air which can 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.

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