Thermal performance analysis of EAHE with and without fins arrangements

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***Abstract*— An Earth air heat exchanger(EAHE) uses the earth as the thermal source and sink for economical, energy efficient, space heating and cooling. The temperature of earth at a certain depth about 4m 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 air is passing throught buried pipes it will become hot in winter and cold in summer as compared to outside temperature.EAHE generally uses for passive heating or cooling.This paper presents effect of temperature drop or rise due to fins in horizontal arrangement. In this paper comparsion of COP v/s Reynolds number,temp difference v/s Reynolds number and Nusselt number v/s Reynolds number will be done**

***Index Terms*— EAHE,Passive cooling,temperature drop,fins etc.**

I. INTRODUCTION

Earth air heat exchanger(EAHE) is an device that permits transfer of heat from ambient air to deeper layers of soil and vice versa. EAHE usually consists of loop(s) of pipes buried in ground horizontally or vertically. Vertical loops go deeper but horizontal loops are generally buried at 2 to 4 meters depth. Temperature regime at this depth and beyond is stable, with no diurnal fluctuation and with only a small seasonal or annual variation. This stability is result of natural physical phenomena Temperature waves dampen as they penetrate through layers of soil. High frequency waves do so more rapidly. Accordingly diurnal fluctuations (one cycle per day) diminish within less than a meter . But the annual wave (one cycle per year) penetrates deeper. Its amplitude of fluctuation is much smaller. Large mass of soil at a stable , near constant, temperature permits its use as sink and source of heat.

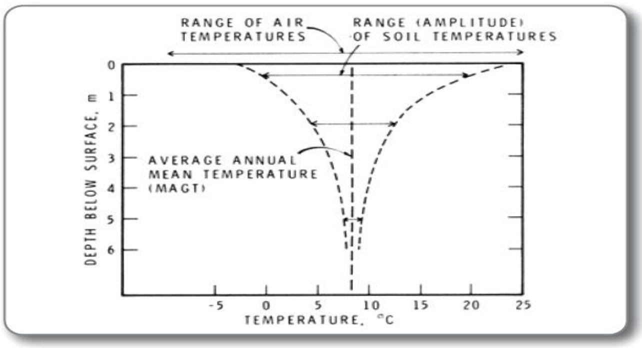

Fig. Variation of temperature with depth

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Ambient air is pumped through buried pipes at moderate velocities. When it is warmer (as in summers) than the basic temperature of soil surrounding the pipes, heat is transferred from air to soil resulting in cooling. In winters or at nights the reverse takes place. Thus, EAHE can be used for cooling in summer and heating in winter.

II. LITERAURE SURVEY

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,

Sehli et al. proposed a one-dimensional numerical model to check the performance of EAHEs 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 airconditioning systems.

Girja sharan shows the results respectively for the months of January when it was operated at night in heating mode and May in cooling mode. It is seen that the ETHE could warm-up the cold air by as much as 12 -13C. It could cool the air in May also by a similar amount, from 40.8C to 27.2C.by using 50 m long single pass MS pipe of 10 cm diameter in arid area of ahemdabad.

Ghosal et al. developed 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 3–4C less in summer than the same greenhouse when operating without EAHE.

Bansal et al. investigated 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

Santamouris et al. investigated the impact of different ground surface boundary conditions on the efficiency of a single and a multiple parallel earth-to-air heat exchanger system.

TYPE OF EAHE

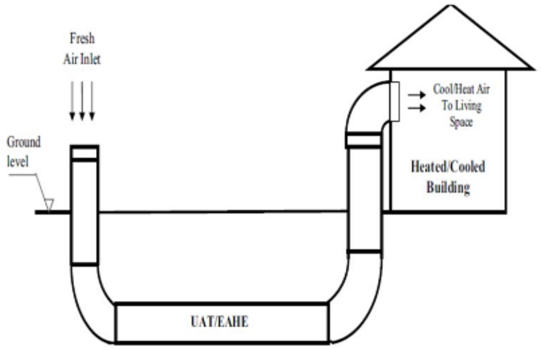
There are two type of Earth air heat exchangers

(a)Open system

(b)Closed system

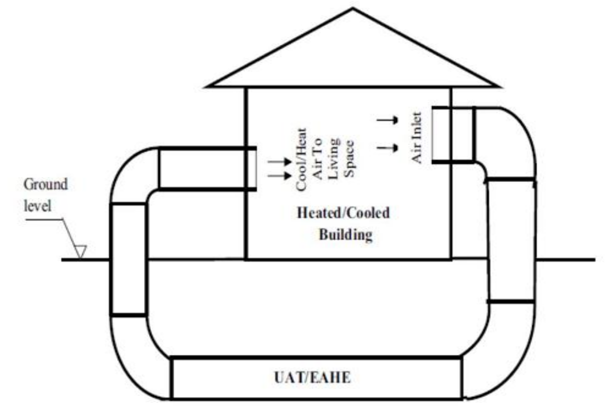
(a)OPEN SYSTEM:

In open systems, 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.



(b)CLOSED SYSTEM:

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



DIFFERENT ARRANGEMENT OF EAHE

Horizontal EAHE:

In this type of arrangement loops of pipes is arranged horizontally. There can be two arrangement series and parallel .

Vertical EAHE:

In this type of arrangement loops of pipes is arranged vertically.These are also sub classified as series and parallel. Combination of these arrangement can be shown as:

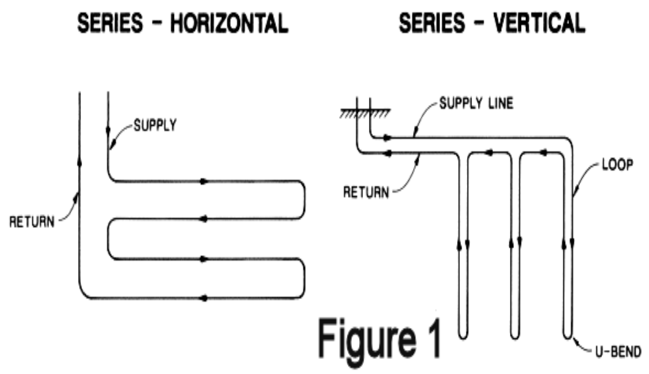


Figure 1

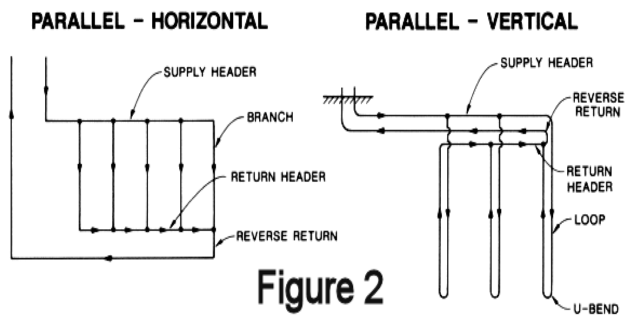
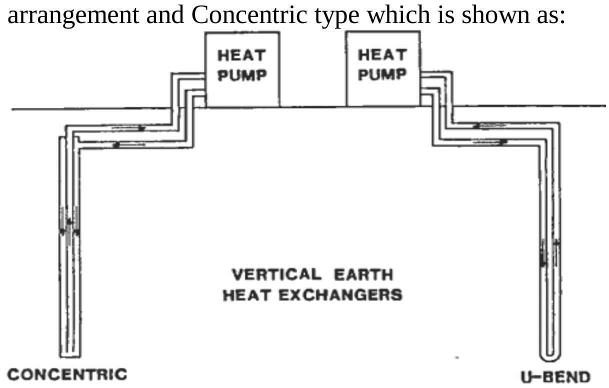


Figure 2

In parallel arrangement there is one more possibility such as U type arrangement and Concentric type which is shown as:



III. METHODOLOGY

PROBLEM FORMULATION

The main objective of my experimental work is to study the variation in cooling effects caused by Earth Air Exchanger in summer climate condition by using fins and without fins in series connection. In summer climate conditions, ground temperature is lower than atmospheric temperature. Hence air flowing through the buried pipe exchange heat with underground earth surface in summer climate condition. In this experiment, blower sucks atmospheric air into the pipe and circulates through the buried pipe, due to which air gets cooled. The cooled air is circulated into the delivery pipe for cooling in summer.

Following Procedure is adopted:-

Inlet and exit temperature is calculated at different mass flow rate.

Coefficient of performance is calculated at different mass flow rate.

Nusselt number is calculated at different mass flow rate

Convective heat transfer coefficient is calculated at different mass flow rate.

To compare whether fins arrangement is better or without fins for horizontal series arrangement.

IV. EXPERIMENTAL INVESTIGATION

To collect data for temperature difference, coefficient of performance and heat transfer coefficient an experimental setup is made especially for the experiment. By taking data from the experiment we compare the performance of Earth Air Heat Exchange for different arrangements i.e. with fins and without fins in horizontal arrangement.

The Earth Air Heat Exchanger in series connection as shown in fig. consists of horizontal pipe of inner diameter of 64 mm with total length of 19 m. Three pipes made up of GI of length 3 m each are connected in series and buried at a depth of 2.5 m in ground with dry soil. The series arrangement of GI pipe is connected to a common intake and outlet manifold for air passage. Atmospheric heric air was sucked during the pipe by means of centrifugal blower by a 3 phase, 2 hp, 230 V and 2800 rpm motor. The blower is used to suck the hot ambient air through the pipelines and delivered the cold air for required place. The mass flow rate of air was measured by orifice meter.

Copper-constantan thermocouples are used to measure the air and pipe surface temperature. Before installation, thermocouple was calibrated under same condition. At the surface of the pipe six thermocouples were inserted which is used to measure surface temperature of the pipe. One thermocouple is inserted at intake and other at outlet to measure inlet and outlet temperatures. All thermocouple were connected to digital temperature indicator by a selector switch. Pressure difference was measured by an U-tube manometer having 0.1 cm least count.

V. MATH

Mean bulk air temperature (Tfav)

Simple arithmetic mean of measured inlet and exit temperatures of air under testing

Tfav = (Ti + To)/2

Where, Ti = Inlet temperature of air in Celsius

Te = Outlet temperature of air in Celsius

Mean Pipe air temperature (Tpav)

Thermocouple wires are arranged at equal distance on pipe.

Hence average reading of all points are

Tpav = (T1 + T2 + T3 + T4 + T5 + T6)/6

Where,

Tpav = temperature of pipe at different locations of pipe

Pressure drop across the orifice plate (ΔP_o)

$$\Delta P = \Delta h \times 9.81 \times \rho_m \times 1/5$$

Where,

Δh = difference of mercury level in U tube manometer

ρ_m = density of mercury 13600 kg/m3

Mass flow rate measurement (m in kg/s)

$$m = C_d \times A \times [2p(\Delta p)/(1-\beta)^4]^{0.5}$$

Where, β =d2/d1

Cd = coefficient of discharge of orifice meter i.e. 0.62

A= Area of orifice plate, m2

p= density of air in kg/m3

Velocity of air (V)

V = m/(ρA)

Where,

A = area of pipe in m2

Reynolds number (Re)

Re = V Dh/

Where,

= kinematic viscosity of air at t in m2/s

Heat transfer rate (Q)

Qa = m x Cp x (To-Ti)

Where,

m = mass flow rate

Cp = heat capacity

Ti = initial temperature

To = final temperature

Heat transfer coefficient (h)

h = Qz / Ap (tpav - tfav)

Where,

Ap is the heat transfer area assumed to be the corresponding pipe area

Nusselt Number (Nu)

Nu = h Dh / k

Where,

k = thermal conductivity

Dh = hydraulic diameter

Coefficient of Performance

Cop = Qa / W

Where,

Qa = Heat Transfer Rate

W = Work done by Blower

VI. Observations

Observation table for series combination 2.5 inch GI pipe without fins

Serial No.	Mercury deflection (cm)	Inlet air temp. (Celsius)	Outlet air temp. (Celsius)	Pipe Temp. (Celsius)	Avg. air temp. (Celsius)	Temp. Difference
1	1	42.51	37.32	35.11	39.91	5.19
2	2	39.22	35.09	34.13	37.15	4.13
3	3	36.76	33.50	32.03	35.13	3.26
4	4	34.12	30.85	29.71	32.52	3.38
5	5	32.43	30.13	27.53	31.28	2.31

Observation table for series connection 2.5 inch GI pipe with fins

Serial No.	Mercury deflection (cm)	Inlet air temp. (Celsius)	Outlet air temp. (Celsius)	Pipe Temp. (Celsius)	Avg. air temp. (Celsius)	Temp. Difference
1	1	43.12	35.89	34.88	39.50	7.23
2	2	39.86	34.32	33.12	37.09	5.54
3	3	37.84	34.23	32.65	35.95	3.45
4	4	35.36	32.21	31.32	33.78	3.15
5	5	31.69	28.82	27.69	30.25	2.87

VII. Results

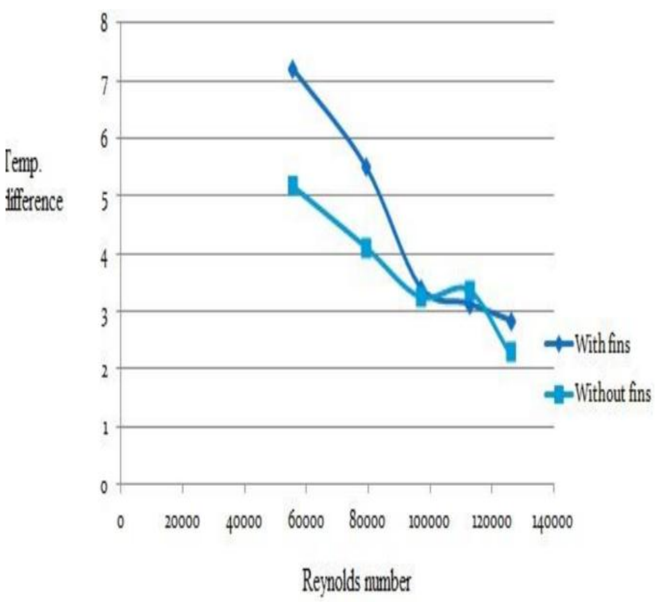
Results of different parameters of 2.5 inch series connection without fins

Serial No.	Reynolds No. Re	Velocity	Mass flow rate Kg/s	Heat transfer Q in watt	Convective heat transfer coeff. h In W m^2/k	Nusselt number No.	cop
1	55268.30	12.91	0.0507	265.44	14.59	26.49	0.1779
2	79026.28	18.91	0.0718	298.73	26.11	65.27	0.200
3	96791.97	22.40	0.0879	285.55	24.57	61.42	0.1933
4	112490.60	25.86	0.101	343.76	32.29	82.02	0.230
5	125765.39	28.91	0.113	263.25	18.50	46.25	0.1768

Results of different parameters of 2.5 inch series connection with fins

Serial No.	Reynolds No. Re	Velocity	Mass flow rate Kg/s	Heat transfer Q in watt	Convective heat transfer coeff. h In W m^2/k	Nusselt number No.	cop
1	55265.30	368.39	0.0506	368.39	21.02	52.56	0.2469
2	79026.11	400.50	0.0718	400.50	31.125	77.81	0.2684
3	96759.23	305.72	0.088	305.72	24.454	61.13	0.2049
4	112492.60	323.54	0.102	323.54	34.71	86.79	0.2168
5	125775.40	317.90	0.110	317.90	32.779	81.94	0.2130

Comparison between fins and without fins arrangement



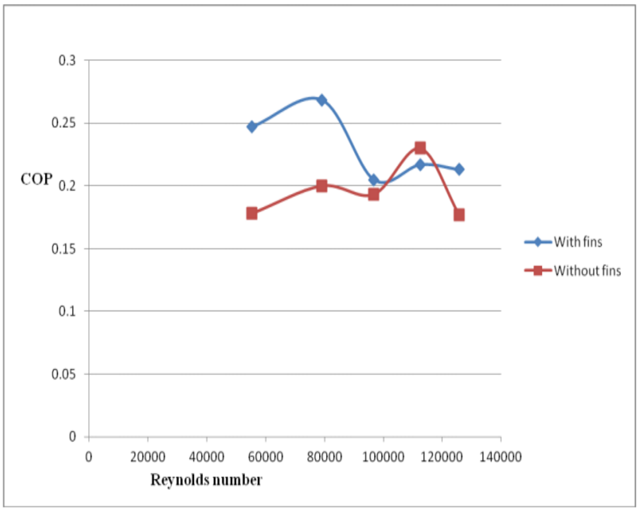
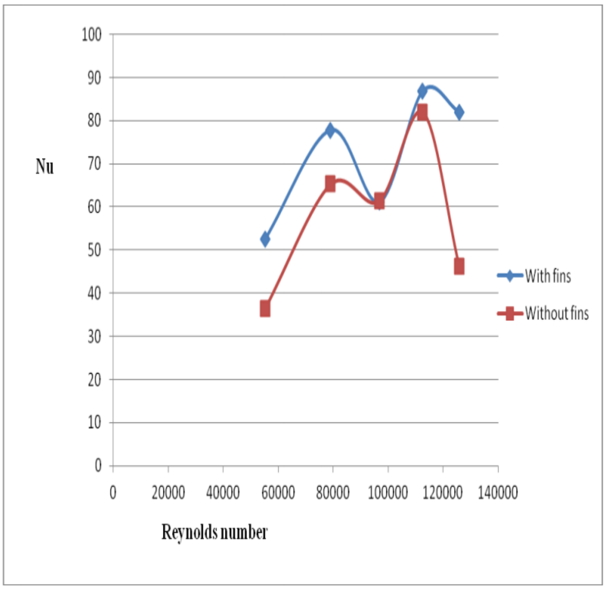


Fig 6.2 Comparing COP and Reynolds number for With and Without fins arrangement



3Comparing Nusselt number and Reynolds number for With and Without combination

VIII. CONCLUSIONS

By observing the table, we found that for series arrangement the temperature difference at the inlet and outlet of the pipe varies from 2.3oC to 5.19oC for 2.5 inch pipe diameter without fins and for 2.5 inch diameter pipe with fins temperature difference varies from 2.87oC to 7.23oC. So as temperature difference variation is more in fin arrangement. So with fins arrangement is better.

By observing the table, we found that for without fins arrangement the coefficient of performance varies from 0.117 to 0.230 at Reynolds number 11200 for 2.5 inch pipe diameter and for 2.5 inch diameter pipe with fins coefficient of performance varies from 0.2049 to 0.2684. So as coefficient of performance variation is more in 2.5 inch pipe with fins up to specific range of Reynolds number.

By observing the table, we found that for without fins arrangement the Nusselt number varies from 36.49 to 82.02 for 2.5 inch pipe diameter and for 2.5 inch diameter pipe with fins Nusselt number varies from 52.56 to 86.79. So as NUSSELT number variation is more in with fins arrangement.

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