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Design, Construction And Performance Evaluation of Earth-To Air Heat Exchanger For Room Heating Applications

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Abstract: *Earth air heat exchanger (EAHX) is a subterranean ventilation system that explores soil temperature below the surface to pre-cool or pre-heat ventilation air. Performance of the earth air heat exchanger varies with climatic and soil condition of the area. In this paper, an Earth air heat exchanger (EAHX) was designed constructed and installed and its actual field performance was evaluated. The results suggested that the earth air heat exchanger alone is not sufficient to create thermal comfort, but can provide significant portion of heating load. The average coefficient of performance (COP) in the cold (Hamadan) was 3.2.The earth air heat exchanger was able to raised the cold ambient air by 3.4^{0}C during cold season*

***Keywords**: Earth to air heat exchanger, Coefficient of performance, Earth undisturbed temperature*

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I. Introduction

In view of over – increasing per capita energy consumption and exponentially rising population, the earth's conventional energy sources are not likely to last for long time. Therefore, well – organized efforts are expected from scientific community to ensure that energy requirement of world at large is assured for long time and at low economic cost. So, it becomes very important to find and explore non- conventional energy sources to meet the energy requirement of the society. The non- conventional energy sources are better option of clean and sustainable energy. This king of energy is, at principle, inexhaustible and can be found and exploited equally well on the plate (Bisoniya *et al*., 2013). The conventional air conditioner (ACs) used for achieving thermal comfort conditions in offices, buildings residential, and industries are responsible for global warming and ozone layer depletion because of the use of chlorofluro-carbons (CFCs) as refrigerants in thes machines. To minimize depletion of the ozone layer and global warming and to reduce high- grade energy consumption, numerous alternative techniques are being currently explored (Bansal *et al*., 2010). One of the promising techniques is earth to air heat exchangers (EAHEs). EAHE is basically a series of plastic, metallic or concrete pipes buried underground at a specified depth, and fresh atmospheric air passes through it. It is the property of earth that the temperature of ground at a depth of 1.5 – 2m remains fairly constant throughout the year. This constant temperature (earth's undisturbed temperature (EUT) remains lower than the ambient temperature in summer and vice versa in winter. The fresh ambient air drawn through pipes of EAHE gets cooled in summer and vice versa in winter and if at sufficiently low high temperature can be supplied directly for heating/ cooling of space. Otherwise, the output of EAHE is connected to the conventional air conditioner (AC). In both cases, EAHX system can be used to save significant amount of electrical energy.Bisoniya *et al*., (2013) gave an extensive literature review covering design, characteristics of EAHX, modelling adopted by several researchers when the earth air heat exchanger was integrated by solar chimney which utilizes both the geothermal energy as well as solar energy, the energy savings were greater compared to uncoupled system.

Chel and Tiwari (2010) analyzed space heating and cooling with an Earth to air heat exchanger integrated stand alone photovoltaic system in New Delhi, India. It was found that the energy payback is less than 2 years on investment in earth to air heat exchanger system and total average coefficient of performance in the experimental period was 10.09. lee and Strand (2012) parametric analysis was carried out to investigate the effect of pipe radius, pipe length, air flow rate and pipe depth on the overall performance of the earth tube under various conditions. As the pipe length and depth increases, the inlet air temperature decreases. Air flow rate and pipe radius increases, the earth tube inlet air temperature also increases. In addition, pipe length and pipe depth tube turned out to affect the overall cooling rate of the earth tube, while pipe radius and airflow rate mainly affect earth tube inlet temperatureMisra *et al*., (2013) conducted an exhaustive parametric analysis on the performance of earth air heat exchanger (EAHX) also analyzed how in continuous operation performance degrades and devised a term "derating factor" to relate this degradation. Their results show a variation of 0 % to

64 % in derating factor which is caused by choosing different parameters like air velocity, pipes dimensions, depth, and soils thermal conductivity.

Givoni (2007) has shown that the potential of the EAHX system in hot climates may however be improved using various soil cooling strategies to lower the natural subsurface soil temperature such as shading, surface irrigation, surface treatment using plants and pebbles.Ghosal and Tiwari (2006) investigated the modelling and parametric studies for thermal performance of anEarth to Air Heat Exchanger integrated with a greenhouse. The thermal model has been developed to investigate potential of using stored thermal energy of ground for greenhouse heating and the cooling with the help of an earth to air heat exchanger system integrated with greenhouse in premises of IIT, Delhi, India. The temperature was risen up to 7 ^{0} C – 8 ^{0} C and 5 ^{0} C – 6 ^{0} C reduction of temperatures for greenhouse air for winter and for summer period respectively, due to incorporation of EAHX as compared to temperatures without the EAHX.Thanu *et al*., (2001) analyzed thermal performance of a Ground Heat Exchanger (GHE) connected to a farmhouse. The farmhouse had six main areas: three bedrooms, a living room, a dining room and a kitchen. The single pass mode of GHE was implemented consisting of two rectangular tunnels measuring 60 cm x 80 cm with a length of 76.5 m. The tunnels were buried at a depth of 4 m. Thermal performance of the Ground Heat Exchanger was analyzed in three seasons: summer, monsoon and winter. The best achievement of temperature reduction was recorded in summer at 14.8 ^{0} C and the worst was in winter with 2 ^{0} C of temperature incrementBansal *et al*., (2012) developed a new concept of 'Derating factor' for assessment of thermal performance of EAHX under transient operating conditions. The authors concluded that under transient conditions, thermal performance of EAHX declines due to continuous use of EAHX for long durationsPeretti *et al*., (2013) discussed the effect of soil cover, climate and soil composition on the performance of the EAHX and concluded that the bare surface improves the performance of EAHX for heating whereas the wet surface is better for cooling purpose. It has also been concluded that higher water content and closely packed soil near the pipes of EAHX improves the performance of the EAHX.

This research is therefore aimed at designing, constructing and evaluating the performance of earth-air heat exchanger for room heating during harmarran period in Sokoto and its environment using cooling test

II. Materials And Experimental Procedures

2.1 Materials

The earth-air heat exchanger was designed and constructed using the following materials;

1. Galvanised steel pipes
2. T type thermocouples
3. 8- channel data logger,
4. digital vane type anemometer
5. Blower.
6. Thermometers
7. Temperature auto scanner

2.2 Experimental procedures

The earth to air heat exchanger designed and constructed in this paper was an open loop system. The system consist of galvanised steel pipes of dimensions 200cmx100cmx350cm with 3cm diameter, thickness of 5mm and was buried at depth 1 m at yard of Sokoto energy research centre, office building, Usmanu Danfodiyo University, Sokoto. The system made up of inlet, parallel and outlet pipes. The ambient air was suck by blower and was allowed to pass through the inlet pipe, and then passed through the parallel pipes buried underground before entering into room through outlet pipe as heat air. The velocity of ambient air before entering into inlet pipe was 11 m/s and measured by a digital vane type anemometer. The vane size is 66x29.2 mm and velocity range 0.3 to 45 m/s. The anemometer measures mean air velocity. The ambient air temperature (inlet) and room air temperature (outlet) were measured by thermometer and earth temperature at depth of 1m was measured using the T thermocouples and recorded with an interval of minutes using an 8-channel data logger. In each of the test to carry out, the temperatures of ambient (inlet) and outlet (room) air are recorded. The velocity of the ambient air was maintained in each of the test.

2.3 Description Of Experimental Set-UP

The experimental set up was an open flow system constructed for experimental investigations on the temperature difference of air flowing through pipes from outside to the inside of the room. The earth to air heat exchanger consist pipe as risers each having 3 cm diameters with total length of 38.5 m. They were made up of steel pipes and buried at a depth of 1 m below the earth surface. Ambient air was sucked through the pipes by means of a centrifugal blower. The blower was used to suck the hot/cold ambient air through the pipe and delivered as cold/hot air to the room. The blower was placed at the inlet to blow the atmospheric air into the pipe for about 15 – 20 minutes to attain the steady state. Velocity of the air at the inlet was measured with the help of anemometer. The thermocouples and thermistor were attached to the temperature auto scanner at the inlet and the outlet to record the temperature change and also at various places below the ground to measure the soil temperature.

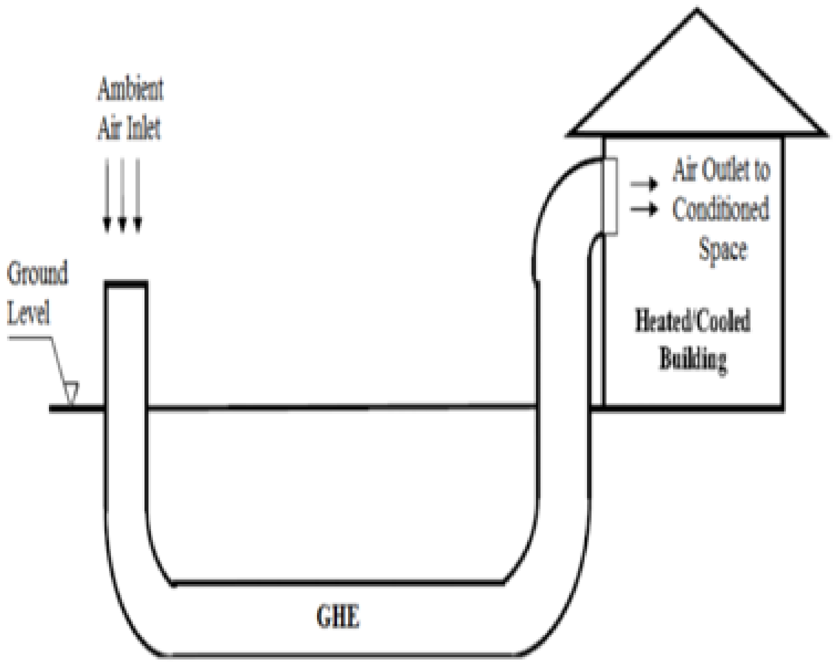

Figure 1.schematic diagram of the experimental set up

2.2 Theoritical Considerations

According to (ASHRAE, 1985) the thermal performance of the earth to air heat exchanger can be evaluated as

$COP = \frac{Qout}{Win}$ 1

$Qout = MaCp(T0 - Ti)$ 2

Qout = Total Heating (J)
Win = Energy use by blower
Where
$Ma =$ Mass flow rate of air through the pipe (kg/s)
Cp = Specific heat capacity of air (J/kg.k)
Ti = inlet temperature of air (^{0}C)
To = outlet temperature of air (^{0}C)

III. Results And Discussions

3.1 Heating Tests

Heating tests were carried out. The system was turned on at 10 am and operated for 8 hours continuously. Temperature readings were noted at hourly interval. The conditions on the three consecutive days were similar and therefore the results were averaged as presented in tables 1 – 3. The ambient temperature started at 21^{0}C increasing to the highest value 30.30^{0}C. Basic soil temperature at 1m depth was constant at 24.2^{0}C. Temperature of the air at the outlet varying from 27.53^{0}C to 40.36^{0}C EAHX was able to raise the ambient air temperature at 5 pm from 21.00^{0}C to 30.1^{0}C.

The COP of Earth to air heat exchanger for heating test was calculated by the flowing equation;

$\boldsymbol{COP = \frac{MC(Tout-Tin)}{power\ input}}$ 3

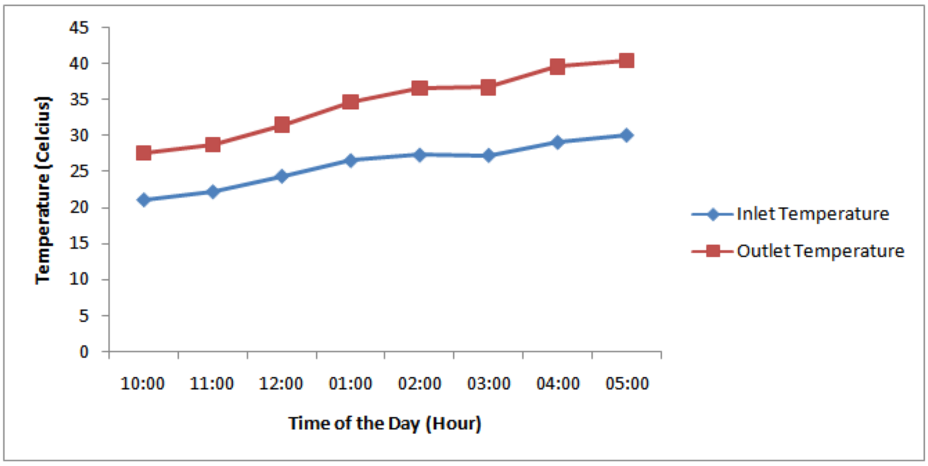

Figure 1: Variations of inlet and outlet temperature with time during the heating tests.

The result from figure 1 presents a comparison between the inlet and outlet temperatures during the winter days time. What is apparent from the figure 1, is that the peak heating exists when outlet temperature was at 40.36^0 C. The inlet temperature started 21.0^0C at 10:00 am then increased to 31.1^0C at 5 00 pm. The outlet temperature was 27.53^0C then increased to 40.36^0C at 5.00 pm. The different between the inlet and outlet temperatures were 10.26^0C. This means that the earth air heat exchanger was able to raise the inlet (ambient) air temperature.

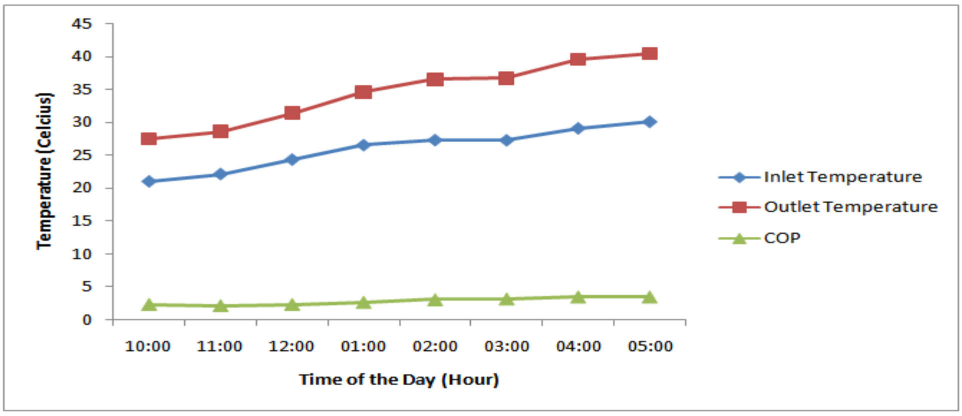

Figure 2: comparison of inlet, outlet temperatures and coefficient of performance with time during heating test;

The results from figure 2 shows a 37^0C difference between outlet and coefficient of performance and difference of 10^0C between outlet and inlet temperatures.

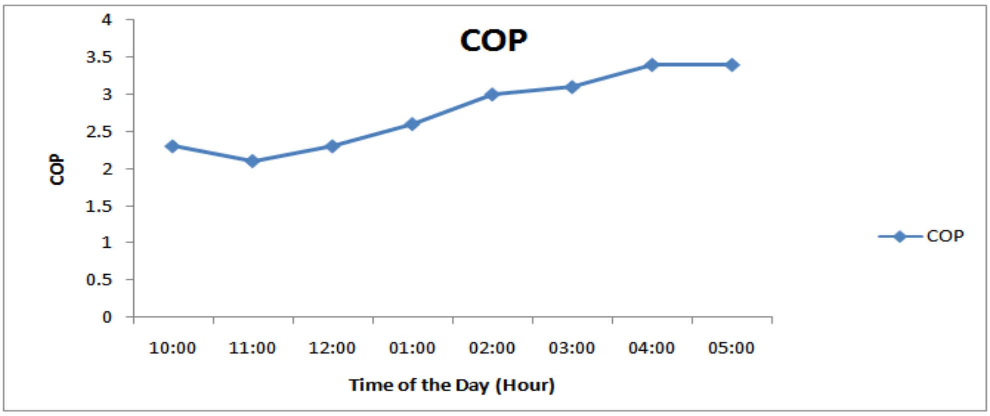

Figure 3 variation of coefficient of performance (COP) with time for heating during winter days.

The heating coefficient of performance gave less result under low ambient temperatures as shown in table 1.

... **Table1** Average inlet temperature, outlet temperature and soil temperature of EAHX

Time/sec.	Ti/°C	To/°C	Ts/°C	M(kg/s)	Cp(J/kg/k)	Qout(w)	Qin(w)	COP
10.00	21.00	27.53	24.2	0.0975	1007.00	695.1	300.00	2.3
11.00	22.13	28.63	24.2	0.0975	1007.00	638.2	300.00	2.1
12.00	24.33	31.43	24.2	0.0975	1007.00	697.1	300.00	2.3
1.00	26.53	34.56	24.2	0.0975	1007.00	788.4	300.00	2.6
2.00	27.3	36.5	24.2	0.0975	1007.00	903.3	300.00	3.0
3.00	27.27	36.66	24.2	0.0975	1007.00	921.9	300.00	3.1
4.00	29.1	39.5	24.2	0.0975	1007.00	1021.1	300.00	3.4
5.00	30.1	40.36	24.2	0.0975	1007.00	1007.4	300.00	3.4

IV. Conclusion

Based on the obtained results, it can be stated that the earth air heat exchanger (EAHX) design, constructed and tested in this work holds considerable promise as means to heat ambient air for variety of applications such as in office buildings. It can also concluded that though the system alone is not sufficient to heat as conventional air condition , but can provide significant portion of heating load to provide thermal comfort.

V. Recommendations

1. The earth air heat exchanger is not in wide use in tropical regions, as a passive heating system; hence it is here by recommended for more applications in the field.
2. Though the results of the heating performance were found to be encouraging it is recommended to have a more control strategy in the operation of the system.
3. To couple the system with conventional air conditioning system for good thermal comfort of the building's interior, as a supplementary heating method.

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