International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 4 ‖ 2022 ‖ PP. 79-85

Experimental Setup of Geothermal Cooling /Heating with Earth Tube Heat Exchanger.

1. Firdosh, 2. Prashant Chouhan 3. Ouvaid khan, 4. Aakash Chandrwansi, 5. Mr. SushantkishorKondhalkar
(Asst.Prof.AITRC) Department of Mechanical Engineering

Abstract
The earth–tube heat exchanger (ETHE) is a promising technique which can effectively be used to reduce the heating/cooling load of a building by preheating the air in winter and vice versa in summer. In the last two decades, a lot of research has been done to develop analytical and numerical models for the analysis of ETHE systems. Many researchers have developed sophisticated equations and procedures but they cannot be easily recast into design equations and must be used by trial-and-error. In this paper, the author has developed a one-dimensional model of the ETHE systems using a set of simplified design equations. The method to calculate the earth's undisturbed temperature (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 developed equations enable designers to calculate heat transfer, convective heat transfer coefficient, pressure drop, and length of pipe of the ETHE system. A longser pipe of smaller diameter buried at a greater depth and having lower air flow velocity results in increase in performance of the ETHE system.

Date of Submission: 28-03-2022 Date of acceptance: 09-04-2022

I. Introduction

Earth tube heat exchanger is an underground heat exchanger that can capture heat from and dissipate heat to the ground. They use the earth near constant subterranean temperature (undisturbed temperature) to warm or cool air or other fluids for residential, agricultural or industrial uses. They are also called earth tubes or earth-air heat exchangers or ground tube heat exchanger. Earth tubes are often a viable and economical alternative or supplement to conventional central heating or air conditioning systems since there are no compressors, chemicals or burners and only blowers are required to move the air. These are used for either partial or full cooling and their use can help building meet passive house standards. In the case of cooling a building, the ground is the heat sink, and the building to be cooled acts as heat source. In the case of heating, these functions are reversed- the ground becomes the heat source and the building heat sink. Heat is extracted from or rejected to the ground by means of buried pipe, through which a fluid flows. The buried pipe is commonly called ground loop heat exchanger. Types of Earth Tube Heat Exchangers: There are two general types of ground heat exchangers: open and closed. In an open system, the ground may be used directly to heat or cool a medium that may itself be used for space heating or cooling. Also, the ground may be used indirectly with the aid of a heat carrier medium that is circulated in a closed system. Open systems: In open systems, ambient air passes through tubes buried in the ground for preheating or pre-cooling and fresh fluid is circulated through the ground loop heat exchanger. This system provides ventilation while hopefully cooling or heating the building's interior. Closed Systems: In closed systems, both the ends of the pipe are kept inside the control environment, which can be a room in case of air and a tank in case of water, the system is said to be closed loop because the same fluid is passed continuously over and over through the loop

Design and Parameters

1. Tube Depth

The ground temperature is defined by the external climate and by the soil composition, its thermal properties and water content. The ground temperature fluctuates in time, but the amplitude of the fluctuation diminishes with increasing depth of the tubes, and deeper in the ground the temperature converges to a practically constant value throughout the year. On the basis of temperature distribution, ground has been distinguished into three zones.

• Surface zone: This zone is extended up to 1m in which ground is very sensitive to external temperature.
• Shallow zone: This zone is extended up to 1-8 m depth and temperature is almost constant and remains close to the average annual air temperature.

• Deep zone: This zone is extended up to 20 m and ground temperature is practically constant. Soil temperature at a depth of about 10 feet or more stays fairly constant throughout the year and stays equal to the average annual temperature [34]. After a depth of 3-4 m in the ground, temperature remains nearly constant

2. Tube length, tube diameter and air flow rate

The total surface area of the ground coupled air heat exchangers is a very important factor in a overall cooling capacity, which can be increased by two ways, either increasing the tube length or tube diameter [8]. Optimum tube diameter varies widely with tube length, tube costs, flow velocity and mass flow rate. A diameter should be selected that it can balance the thermal and economic factors for the best performance at the lowest cost. The optimum is determined by the actual cost of the tube and the excavation. Excavation costs in particular vary greatly from one location and soil type to another. The optimum tube length was determined by passing the air from the blower at different lengths. The air was passed through the inlet at the minimum speed of the blower i.e 7 m/s and at the length of 9m, the outlet velocity was 1.8 m/s, any further increase in length used to reduce the velocity at outlet which was not required. The 5 cm diameter pipe was considered for the experiment.

3. Tube material

The tube is the main element of ETHE. There are certain properties we have to take into consideration while finalizing the tube material. Tube material must have good thermal conductivity, strength, corrosion resistance, durability, and the cost of the tube material. 1. Copper has a thermal conductivity of 385 W/mk. 2.Aluminium has a thermal conductivity of 205 W/mk. 3. Brass has a thermal conductivity of109W/mk. 4. Iron has a thermal conductivity of 79.5W/mk. 5. Steel has a thermal conductivity of 50.2 W/mk. 6. PVC has a thermal conductivity of 0.19 W/mk. We take aluminium as a tube material. It has good thermal conductivity, better corrosion resistance, and cheaper in cost.

Formulas and function

Here is a list of formulas we consider while calculating the length of earth tube heat exchanger, and efficiency of the earth tube heat exchanger at a different velocity.

1. Mass flow rate

m = (v x ρ x π x Di
2)/4

2. Reynolds number

3.Prandtl number

4.Nusselt number

5. Convective heat transfers Co-efficient per unitlength

h = Nu kair
Do

6.Overall heat transfer coefficient

7. Effectiveness

8. NTU

9. Amount of heat transfer

Q = m Cp (Tout - Tin)

10. Coefficient of performance

COP = m Cp (Tout - Tin) / Power input

By using above these formulas, we found out the length of ETHE. Calculation results are given below

Table-1 INPUT PARAMETERS

No.	Input parameters	Symbols	Value	Unit
1.	Inlet Temp.	T_{in}	40	°C
2.	Length of Tube	L	35	meter
3.	Pipe wall temp.	T	25	°C
4.	Thermal conductivity of the Air	k_a	0.0266	W/mK
5.	Thermal conductivity of the pipe	k_P	205	W/mK
6.	Thermal capacity	c_p	1006	J/KgK
7.	viscosity	μ	1.84×10^{-5}	N/ms
8.	Density of the Air	P	1.1465	Kg/m^3
9.	Velocity of the Air	v_a	1.5,2,3,4	m/s

10.	Outer dia. of the pipe	D_o	0.18	m
11.	Inner dia. Of the pipe	D_I	0.15	m
12.	Outer radi.of the pipe	R_o	0.09	m
13.	Inner radi.of the pipe	R_I	0.075	m

Dimensionand Cooling Capacityofan Experimental Setup

Length of an experimental setup = 3.048m Height of an experimental setup = 1.585m Breadth of an experimental setup = 1.128m

There are two methods to calculate cooling capacity (By reference of living area).

(1) Area Method

(2) Volume Method We used volume method.

Cooling capacity = (10feet) X (5.2feet) X (3.7feet)/1000

= 0.1924 ton

Lengthof Earth Tube Heat Exchanger

We are calculating the length of the earth tube heat exchanger for that we are considering a minimum temperature drop is equal to 10°C. All the input parameters are mentioned in the above table. 1. Mass flow rate (m) = 0.0608 Kg/sec

2. Reynolds number (Re) =28039.4022

3. Prandtl number (Pr) =0.6959

4. Nusselt number (Nu) = 66.3627

5. Convective heat transfer coefficient per unit length (h) = 9.8069 W/m2K

6. Overall heat transfer (Ut) = 9.7933

7. Effectiveness = 0.7

8. NTU = 1.2 9. Length of tube = 20.89 (Approx. 21m) 10°C temperature drop is achieved when the length of ETHE is equal to 21m. Now we have calculated the change in outlet temperature when the velocity of a fluid change from 1.5, 2, 3, 4m/sec, and COP of the system. The results are shown in the below table.

Table – 2. OUTLET TEMPERATURE, HEAT FLOW, COP AT DIFFERENT VELOCITY.

velocity	1.5	2	3	4
m	0.030	0.0405	0.0608	0.081
Re	14019.7	18692.9	28039.4	37385.9
Pr	0.6959	0.6959	0.6959	0.6959
f	0.0287	0.0266	0.024	0.0224
Nu	38.3481	48.6212	66.3627	82.8448
h	5.7409	7.1851	9.8069	14.6911
U_t	5.7362	7.1778	9.7933	14.6605
NTU	1.9	1.721	1.5	1.032
€	0.85	0.8	0.7	0.6
T_{out}	27.25°	28°	29.5°	31°
Q(w)	384.795	488.916	642.230	733.374
Q(ton)	0.109	0.139	0.183	0.209
COP	1.5	1.9	2.5	2.9

The experimental set-up was established at the Annie Institute of Technology And Research Centre ,Chhindwara (M.P) India. Latitude 36.19 and longitude44.01 . The weather conditions for average values (monthly average maximum, minimum and mean ambient temperature, the monthly averages of relative humidity, wind velocity, solar radiation and average soil temperature at 4 m /sec depth for the cooling season are given in Table 3.

TABLE 3 :THE SOIL TEMPERUTURE OF ERBIL OVER COOLING SEASON OF 2021-2022

Conditions	Month			
Mean soil temperature at 3 m depth (˚C)	May	June	July	August`
	19.8	23.2	24.5	25.5

TABLE 4 : MEAN OUTSIDE TEMPERATURE PROPERTIES.

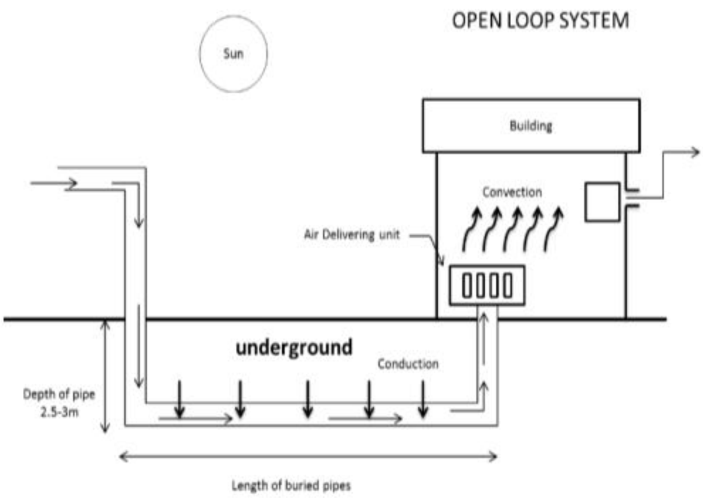
1.	Outside temperatures properties			
Month	Temp ˚C	RH %	H kJ/kg	V m3/kg
January	6.366567	75.74373	17.67	0.7975
February	9.870881	55.66071	20.46	0.871
March	14.06	53.41	27.54	0.8205
April	20.26437	47.2463	38.06	38.06
May	27.83224	28.58423	44.92	0.8616
June	33.33875	19.69074	49.55	0.876
October	22.77146	37.46057	39.26	0.8469
November	14.46116	51.65185	27.84	0.8216
December	8.875603	74.20072	22.077	0.8056

Classification of ETHE

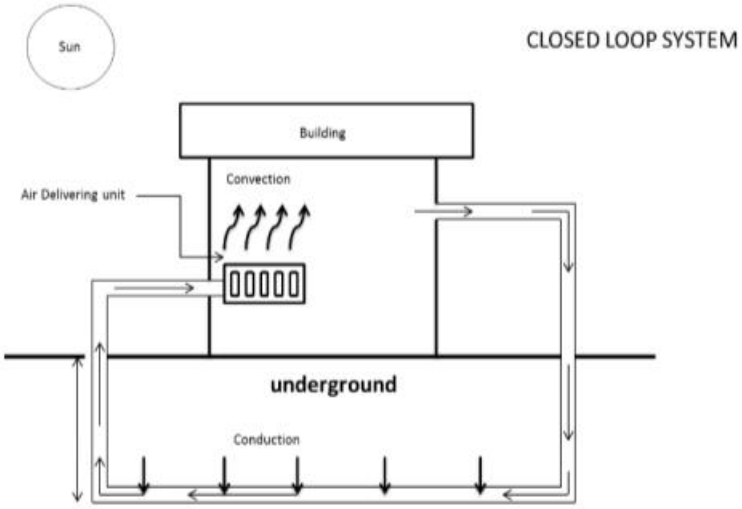
awayThe ETHE systems are design on the basis of three configurations: open loop system and closed loop system and hybrid system .

Open loop System: The ambient air is passed through the buried pipes for pre-heating or pre-cooling of air as. Then the air passes through a conventional system to cool down or get warm up before entering the space. The air is then passes through the ventilation. Woodson et al.used open loop ETHE design with PVC pipes having 5length of 25m, diameter 125mm buried at a depth of 1.5m. The pipes were laid in serpentine pattern. It was seen the air drawn from outside reduces temperature by more than 7.5°C.

The outdoor temperature varied from 25°C to 43°C and the soil temperature of 30.4°C remained the same at a depth of 1.5m.



Closed loop system: : Closed loop systems are also known as earth coupled system as shown in figure . Air sucked from inlet travels through a loop of pipes buried underground and extracts the heat from ground . The ground loops are arranged either vertically or horizontally. The vertical loops are more expensive than horizontal loop. Closed loop are efficient than open loop system. Closed loop system reduces the problem of humidity.



Hybrid Systems:

The ETHE is coupled with other heating/cooling devices such as air conditioner, heaters, solar chimney, solar air heaters etc. These devices improve the comfort and efficiency of the ETHE systems. Researches like Jakhar et al. coupled the Earth to air heat exchanger with a solar air heating duct. The aim was to evaluate the heating 6potential of ETHE with or without solar air heating duct. TRNSYS 17 was used as the simulation tool. Results were validated with an experimental setup in Ajmer, India.

Evaluation was done for inlet flow at different inlet temperature. The experiment was concluded that at a depth of 3.7m and length of 34m, optimum outlet temperature can be achieved. Sikarwar et al.made a conjunction of the ETHE system with air conditioner to reduce the energy consumption and to improve the COP. Results showed that under extreme summer and winter seasons, ground coupled condenser is seen feasible with air conditioner. Chlela et al.made a conjunction of ETHE with heat recovery balanced ventilation system to investigate the energy consumption and thermal comfort. It was found that the ETHE system reduce the energy consumption and control the CO2 emissions and to ensure good thermal comfort. Nowadays hybrid ETHE has become one of the prominent technologies to increase the efficiency of the system.

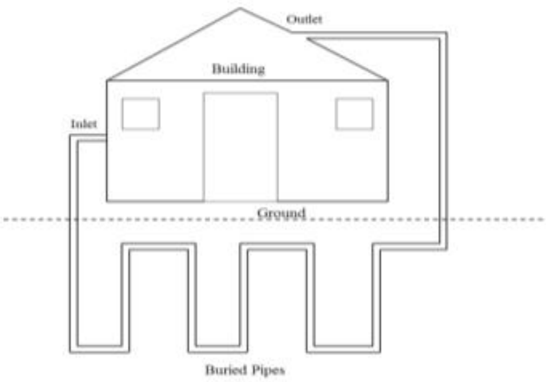
The ETHE are also classified on the basis of pipe layout in the ground and according to mode of arrangement .

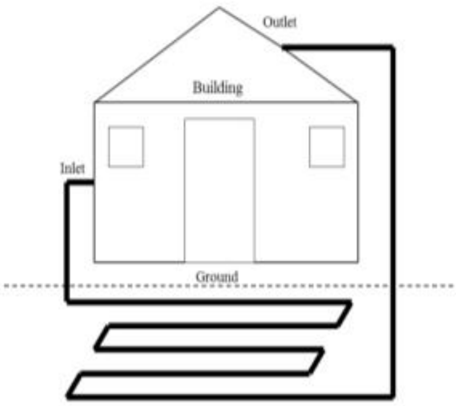
On the basis of pipe layout, the ETHE classified as:

- Horizontal / straight Loop
- Vertical Looped
- Slinky / spiral Looped
- Pond / Helical Looped

On the basis of mode of arrangement ETHE are classified as:ϒ One tube system

- Parallel tube system





One tube system is not appropriate to meet the requirements of an air conditioning system in a building. This is because the tube is too large for the use in generation. Parallel tube systems are used as it reduces the pressure drop and increases the thermal performance of the system.

II. RESULT AND DISCUSSION

The results are summarized under the following points:

- The experimental setup consisted of a 21 m long Aluminium tube buried at a depth 3.5 m and having a diameter of 0.15 m. A 250 W blower is used for transporting the air in an open-loop system.
- 10°C temperature drop is considered to calculate the optimum length for ETHE.
- Theoretical calculations were carried out for different fluid velocity, which are 0.15m/sec, 2m/sec, 3m/sec, 4m/sec respectively.
- It has been observed that if the fluid velocity increases the heat transfer rate through the heat exchanger is decreases. With the minimum heat transfer rate, the temperature drop is also decreased compared to a low fluid velocity.
- But as an air velocity decreases pressure inside the heat exchanger also decreases. Therefore 2m/sec to 4m/sec is an appropriate range from air velocity.
- The tube material is one of the most important parameters while designing ETHE.

We know that increased length would meanincreased heat transfer rate. But after, a certain length no significant heat transfer occurs. So, the tube material will help to increase the heat transfer rate.

- Aluminium has high thermal conductivity and good corrosion resistance, because of this property better amount of heat transfer takes place through the heat exchanger. Therefore, we used aluminium as a tube material.
- COP of the system is also increased from 1.5 to 2.9. With increasing fluid velocity in the system from 1.5m/sec to 4m/sec.

III. CONCLUSIONS

In this paper design of Earth Tube Heat Exchanger (ETHE) and an analytical model is generated. The experimental setup consisted of a 21m long Aluminium tube with a diameter of 0.15m. NTU method is used for theoretical calculation. The present work shows that air velocity is inversely proportional to the heat transfer rate. As velocity increases temperature drop decreases. 21m is calculated as an optimum length for ETHE. Lower air velocity gives better cooling and heating but optimum air velocity is required which is in a range of 2m/sec to 4m/sec.

OBJECTIVE OF THE STUDY

The objectives laid out in reference to the contention above are as:

• To study the cooling and heating potential of ETHE by utilizing four different pipe geometries and materials by virtue of temperature reduction.

• To investigate and assess the best pipe geometry and material for ETHE in Indian climatic condition by employing CFD.

• The prediction of temperature reduction and recommendation of optimum pipe geometry and pipe materials under Indian climatic conditions.

• To understand the variation of pressure (ΔP), Reynolds number (Re), Prandtl number(Pr) and Nusselt number (Nu) for different pipe geometries and materialsThe objectives laid out in reference to the contention above are as:

• To study the cooling and heating potential of ETHE by utilizing four different pipe geometries and materials by virtue of temperature reduction.

• To investigate and assess the best pipe geometry and material for ETHE in Indian climatic condition by employing CFD.

• The prediction of temperature reduction and recommendation of optimum pipe geometry and pipe materials under Indian climatic conditions.

• To understand the variation of pressure (ΔP), Reynolds number (Re), Prandtl number(Pr) and Nusselt number (Nu) for different pipe geometries and materials

REFERENCES

[1]. J. Xamán, I. Hernández-Pérez, J. Arce, G. Álvarez, L. Ramírez-Dávila, and F. Noh-Pat, "Numerical study of earth-to-air heat exchanger: The effect of thermal insulation," Energy and buildings, vol. 85, pp. 356-361, 2014.

[2]. D. Belatrache, S. Bentouba, and M. Bourouis, "Numerical analysis of earth air heat exchangers at operating conditions in arid climates," International Journal of Hydrogen Energy, vol. 42, pp. 8898-8904, 2017.

[3]. F. Fazlikhani, H. Goudarzi, and E. Solgi, "Numerical analysis of the efficiency of earth to air heat exchange systems in cold and hot-arid climates," Energy Conversion and Management, vol. 148, pp. 78-89, 2017.

[4]. F. Ascione, L. Bellia, and F. Minichiello, "Earth-to-air heat exchangers for Italian climates," Renewable energy, vol. 36, pp. 2177-2188, 2011.

[5]. J. Vaz, M. A. Sattler, R. d. S. Brum, E. D. dos Santos, and L. A. Isoldi, "An experimental study on the use of Earth-Air Heat Exchangers (EAHE)," Energy and buildings, vol. 72, pp. 122-131, 2014.

[6]. V. Bansal, R. Misra, G. D. Agrawal, and J. Mathur, "Performance analysis of earth–pipe–air heat exchanger for summer cooling," Energy and buildings, vol. 42, pp. 645-648, 2010.

[7]. S. Menhoudj, M.-H. Benzaama, C. Maalouf, M. Lachi, and M. Makhlouf, "Study of the energy performance of an earth—Air heat exchanger for refreshing buildings in Algeria," Energy and buildings, vol. 158, pp. 1602-1612, 2018.

[8]. R. Misra, V. Bansal, G.D. Agarwal, J. Mathur, T. Aseri, "Thermal performance investigation of hybrid earth air tunnel heat exchanger" Energy and Buildings, vol. 49, pp 531–545, 2012.

[9]. W. Leong, V. Tarnawski, and A. Aittomäki, "Effect of soil type and moisture content on ground heat pump performance: Effet du type et de l'humidité du sol sur la performance des pompes à chaleur à capteursenterrés," International Journal of Refrigeration, vol. 21, pp. 595-606, 1998.

[10]. J. E. Bose, J. D. Parker and F. C. McQuiston, "Design/ Data Manual for Closed-Loop Ground-Coupled Heat Pump Systems," American Society of Heating, Refriger-ating and Air-Conditioning Engineers, Atlanta, 1985.