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PERFORMANCES OF EARTH AIR TUNNEL HEAT EXCHANGER: A REVIEW

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Abstract: *This research paper explores the review of earth air tunnel heat exchanger in term of their performances. variety in expectations for everyday comforts and populace development prompts expanded worldwide energy utilization. Human solace consistently assumes an imperative part in utilizing various intends to lessen the impacts of climate conditions. The structure area catches roughly 40% of the worldwide energy and it is most usually utilized for cooling and for warming of the space involved because of the utilization of machines, Earth air pipe heat exchanger is one of the latent cooling and warming innovation utilized for the indoor warm solace of the tenants. This paper means to introduce the review on the performance study and mechanical improvement of EAHE at various environment condition.*

Key Words: Earth tube heat exchanger, Earth Undisturbed temperature, Geo thermal heat exchanger, Earth air cooling tunnel

1. INTRODUCTION

Factors suchas rising electricity prices and environmental factors have forced us to look for cheaper and cleaner alternatives for various applications. Water or air heating and cooling is one such device that heavily consumes electricity and its emissions are detrimental to the environment. The shortfall in powersupply and demand in my country limits the applicability of heating and cooling water. One of the most promising energy alternativesthat can solve the above problems and we have available is geothermal energy. It is a clean energy, because its use does not emit any type of pollution, and renewable energy is because the heat inside the soiliscirculating, so we are sure that there will always be heat available for us touse.Geothermal heat exchangers are underground heat exchangers that can capture heat and/or dissipate heat underground. They use land near a constantsoil temperature to heat or cool air or other fluids used foragricultural,residential, and industrial purposes.Floormounted heat exchangers can be used in heating or cooling mode, depending on the weather and season. There are many different configurations available to fabricate ground coupled heat exchanger systems. These systems can use open and closed loops, different fluids, or any combination in the system all to optimize ground coupled heat exchangers.

Design parameters that affect the performance of the ground-coupledheatexchanger are tubedepth,tubelength,tubediameter,wind speed, airflow,tubematerial,and tubearrangement.

Depending on the design of underground pipes, there are four different types:

1. Horizontal/ straight Loop 2.Vertical Looped

3. Slinky/ spiral Looped 4. Pond/Helical Looped

Soil temperature at the depth of below 4-meter constant throughout the year and it is equal to average annual ambient air temperature.

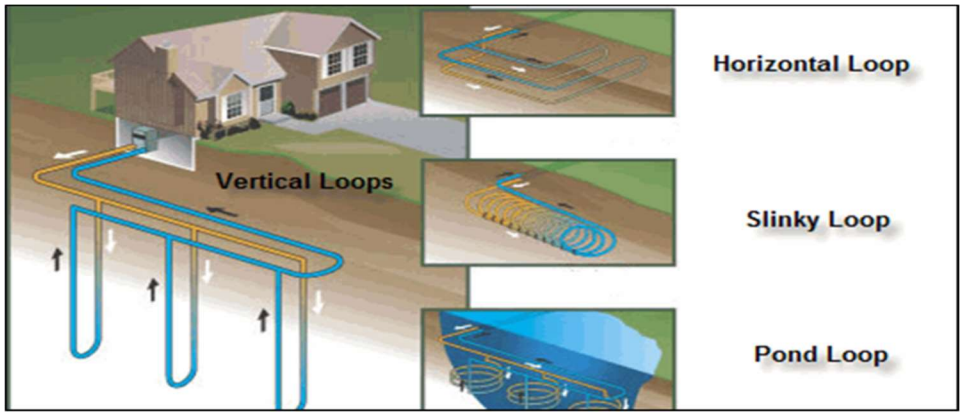

Figure 1: Ground Coupled Heat Exchanger Loops

The advantages of geothermalheatexchangers:high efficiency, low energy consumption, low energy costs, low maintenance costs, low maintenance costs,residential-sizedmodular units, no complicated controls, no outdoor equipment, quiet operation, and increasedoccupantsHigh comfort,low-source energy consumption and low emissions ofair pollutants: green technology reducescabin space.

Disadvantages of geothermalheatexchangers: the initial cost may be higher than traditional systems, not all types of systems are suitablefor all locations, thenumber of designers is limited, and the construction of factories will have a negativeimpacton the stability of the terrain.

1.1. IMPACT OF DIVERSE PARAMETERS ON EATHE

1.1.1. EFFECT OF MATERIAL

At first steel pipes were utilized for the development of EAHE however, then, at that point tests were led for various materials. It is seen that PVC material additionally give the comparable execution consequently utilize less expensive material like PVC rather moreover their life is more. However, steel has higher conductivity than that of PVC yet the variety in temperature of the air at the outlet of line among steel and PVC is minuscule. Consequently, it tends to be reasoned that in EAHE framework, convective warmth move assumes a more significant part than conductive warmth move.

1.1.2. EFFECT OF VELOCITY OF AIR INSIDE PIPE

The impact of speed of air within pipe is shown in Fig. 2. The reduction in temperature of air at the exit of pipe because of increment in air velocity happens as a result of once the air velocity is exaggerated from 2.0 to 5.0 m/s, the convective heat transfer constant is increased by 2.3 times, whereas the length to that the air remains to bear with the bottom is reduced by an element of 2.5. therefore, 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 because of reduction in time of contact the performance gets scale back.

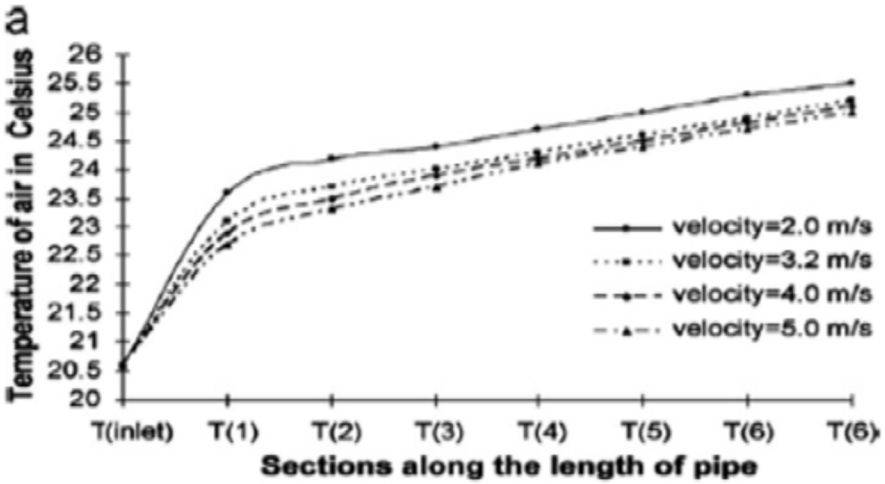

Figure 2: Effect of velocity of air inside the pipe

1.1.3. EFFECT OF TUBE LENGTH

It may be terminated that up to some extent length matters when an explicit length no improvement within the performance is found but massive its length might be. It can be inferred that, for all the thought of climates, lengths of about 10 m are unsatisfactory, whereas important benefits don't occur for lengths over 70 m. The impact of temperature on tube length is diagrammatically described in Fig. 3.

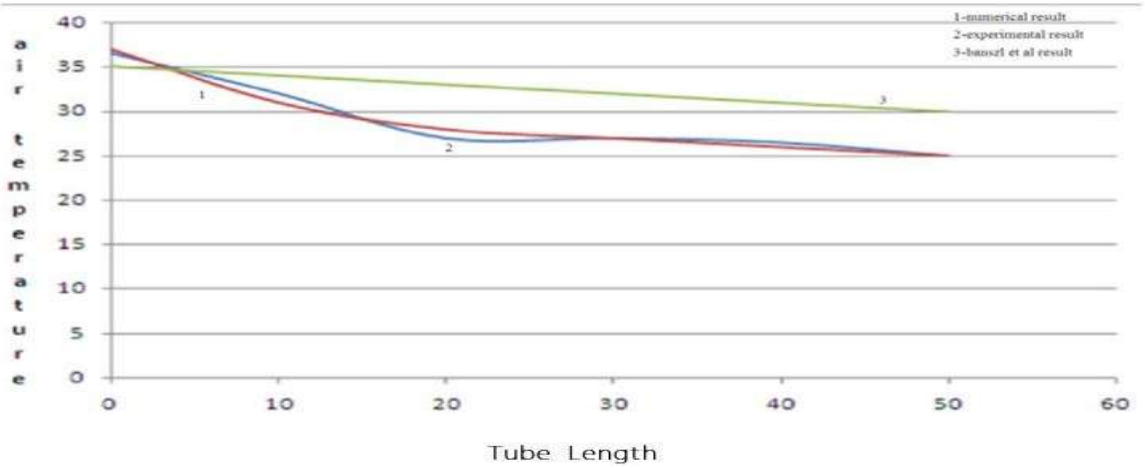

Figure 3: Effect of tube length

1.1.4. EFFECT OF TUBE DEPTH

The ground temperature is plagued by the external climate and soil composition its thermal properties and water content. The temperature of soil fluctuates however become stable once some depth. This temperature remains same throughout the year. From Fig. 4 it's terminated that after a

depth of 1.5 meters this temperature becomes stable that the depth taken ought to be over 3.5 meters depth is additionally not excusable.

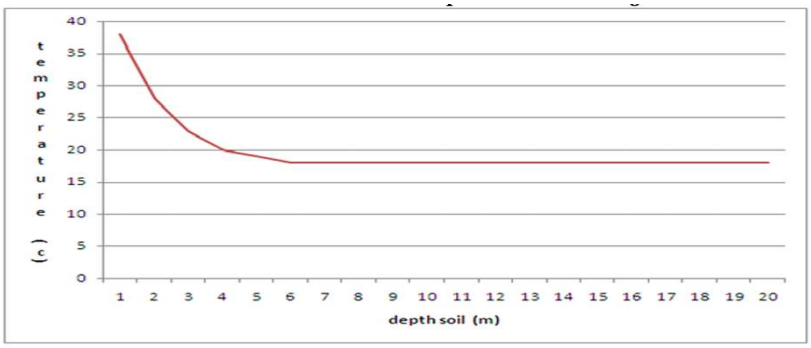

Figure 4: Effect of tube depth

1.1.5. EFFECT OF TUBE DIAMETER

Cooling capability depends on the general area that is a keyway in planning it. this may be affected in 2 ways in which by dynamic length and diameter of the pipe. From Fig. 5, it's discovered that on increasing the diameter the mass flow gets reduced and a lot of length will increase pressure drop and increases the blower input. The optimum answer is that the parallel tube of correct length and diameter are used. The air quickly reached the ground temperature so larger tubes don't seem to be needed.

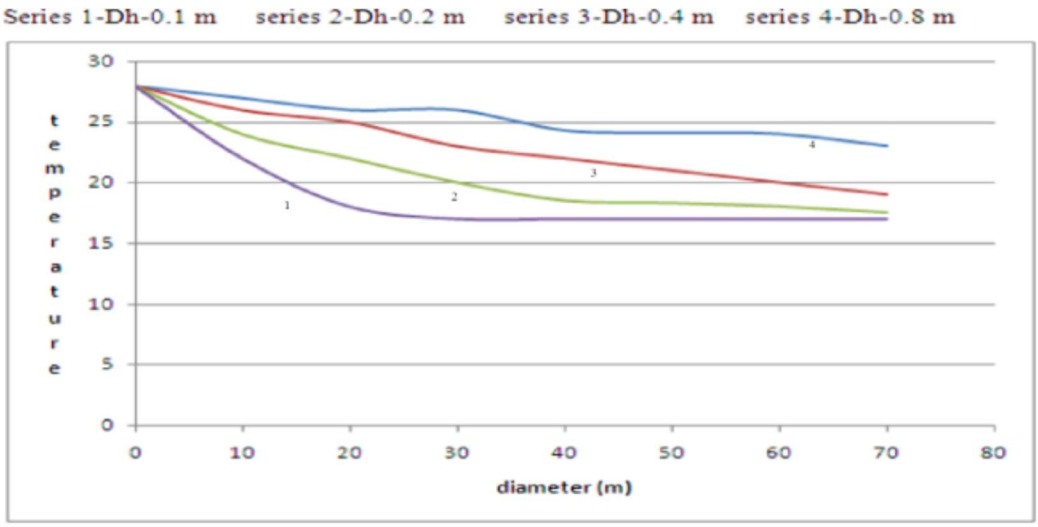

Figure 5: Effect of tube diameter

2. LITERATURE REVIEW

Chao Zeng,Yanping Yuanetal (2019) reported that as the existing tunnels, a strategy exploiting the designing's passage as a EAHE to cool the underground diesel generator rooms in defensive designing was created. A technique of ascertaining prescribed stream speed was proposed to fulfil the need of infrared, disguise initially. A parametric report was completed to explore the effect of the boundaries on warm and infrared disguise execution. The infrared-disguised span, during

which the contrast between the outlet temperature of the EAHE framework and surrounding temperature was under 2 °C, is the record assessing infrared assurance rate. It shows that the more drawn out the passage, the better the cooling impact.Asthe current passages in the defensive designing are utilized as an EAHE, appropriateness is concerned. The main factor affecting the cooling impact and the infrared disguise impact is the released heat from the diesel motor. Moreover, lower soil temperature, higher normal outside temperature and more modest abundance of the open-air temperature prompted better cooling impact and longer infrared disguise ensured length. Consequently, this framework is more appropriate for regions with low soil temperature, high, open-air normal temperature also, little temperature contrast among day and night. In future work, the creator intends to explore the use of assistant-cooling gear for this framework to meet the long-haul infrared cover and energy-saving prerequisite.

Mahendra Kumar Vermaetal (2020) studied that EAPHE framework was clarified as an amazing alternative for indoor warm solace in the structure region. Numerous analysts have been keen on fostering the different models to advance the effectiveness of the framework, just as to fundamentally utilize latent energy. The general analysis has finished up the best operational state of the EAPHE framework through various trial and logical models. In tests, most specialists finished the dirt profundity between 0.5 meters and 4 meters for an ideal result/result. The investigation shows that EAPHE is the most ideal approach to utilize latent energy and lessen ozone harming substance discharges through the traditional cooling framework.To improve the productivity and viability of the EAPHE framework it is important to treat the soil to expand the warm conductivity of the soil. For this, various strategies of concealing, soil dousing, utilization of short grass, and so on were applied.The overall investigation of different trial or logical research utilizing diverse bi-dimensional or three-dimensional models has assisted with understanding the methodology of innovation under various conditions. The entire article showed every one of the variables answerable for the viability of the EAPHE framework and furthermore exhibited the benefits and inconveniences of various framework boundaries to upgrade the warm capability of the framework. Execution of the EAPHE framework is free of the line material subsequently utilization of modest PVC pipes is encouraged. Long lines with little breadth give better execution contrast with the bigger distance across. Yield pipe tallness is additionally a significant factor influencing the warm effectiveness of the framework; it is prescribed to guarantee an ideal outlet stature for a superior yield.

SanjeevJakhara, Rohit Misrabetal (2015) reported in their research that trial analysis has been completed to assess the warm exhibition of EATHE combined with solar air warming conduit implied for warming the air during winter season for a bone-dry environment of Ajmer city, situated in north-western India. The exhibition of three different game plans was analysed. Exploratory outcomes showed that the warming limit of the independent EATHE system (Mode-II) improves when it is helped by solar air warming channel (Mode-III, in which complete air from the EATHE is additionally warmed by solar air warming conduit and afterward provided in the room). It was tracked down that the warming limit of EATHE framework got expanded 1217.625–1280.753 kWh when it was combined with solar air warming channel with a considerable

expansion in room temperature by1.1–3.5◦C higher than the base case (Mode-I). As seen in the third method of activity, appropriate coupling of EATHE with solar air warming conduit may significantly expand the warming limit of EATHE system. Test after-effects of the examination affirmed that the EATHE system combined with solar air warming conduit is very compelling for air warming during winter as it expands the COP of the framework up to 4.57 with solar air warming pipe for a similar force utilization. It is likewise inferred that more than 82–85% of the complete expansion in temperature of air along the EATHE pipe is acquired at a length of 34 from the delta. Accordingly, the expense of the framework can be enhanced by decreasing the passage length to 34 m.

Ganguly, A., & Ghosh, S. (2011) presented a review paper on different methods of evaporative cooling applied to a greenhouse in the last two decades. But presumably,neither of these methods isperfect, especially for areaswith high humidity. The ground air heat exchanger integrated with the greenhouse can reduce the indoor air temperature by 3 to 4 ° C, but this integrated system facesmany operational problems. Apart from high installation cost associated with digging of soil, there are problems related to maintenance as the buried pipes are subjected to corrosion. The use of phase change materials and aquifer cavity flow heat exchangersto store energy in a greenhouse has shown promising results. There are not many reportsof work in these areas and more research is needed inthese areas. Only a few studies involve integrated energy generation and storage systems based on solar energy or other renewable energy for greenhouse applications. For greenhouses equipped with artificial cooling and ventilation systems,low-cost accessto uninterrupted power is an important factor, especially for developing countries like India. Future work should be devoted to the establishment of off-grid greenhouses with dedicated and independent power generation systems.These integrated systems areexpected to make this technology more attractive from a technical and commercial point of view in the coming years.

Trilok Singh Bisoniyaetal (2013) studied that at a depth of regarding 1.5 to 2 m the temperature of ground remains nearly constant. This constant temperature is termed earth's undisturbed temperature. The earth's undisturbed temperature remains incessantly on top of that of shut air temperature in winter and also the different means around in summer. To utilize efficiently the heat capability of earth EAHE system is to be designed. The outlet of EAHE scan be connected to plain air-conditioning unit if cooling or heating achieved is not enough. the utilization of inexperienced and clean energy in or minimize waste material. emissions and to cut back typical energy consumption are in prime focus everywhere. The EAHE systems can play a vital role in minimizing energy consumption by preheating air for heating. of different kinds of buildings in winter and also the different means around in summer. Commonly, the thermal performance of EAHE systemincreases with increase long and depth of burial of pipewhile the decline in performance is ascertained with increase in pipe diameter and air speed. The hybrid systems of EAHE and renewable energy sources like star and wind energy will additionally improve performance of EAHE system.

Ravindra Singh Jhala1, Vikas Bansal,etal(2016) reported that EATHE could be a promising choice from energy conservation purpose of read, and it extensively used for

contemporary inexperienced building for house heating and cooling. The COP of such a system found beyond the standard AC. The performance of EATHE extremely depends on the depth of buried pipe, and it should be optimized. The length, diameter and air rate square measure different parameters, that have an effect on the performance of a system. At a depth of concerning one.5 to two m the temperature of ground remains virtually constant. This constant temperature is named earth's undisturbed temperature. The earth's undisturbed temperature remains continuously beyond that of close air temperature in winter and contrariwise in summer. To utilize expeditiously the warmth capability of earth EAHE system is to be designed. The outlet of EAHEs will be connected to traditional air-conditioning unit, if cooling or heating achieved isn't spare. the employment of inexperienced and clean energy so as to reduce chlorofluorocarbon emissions and to reduce typical energy consumption is in prime focus all over. The EAHE systems will play an important role in minimizing energy consumption by preheating air for heating of various forms of buildings in winter and contrariwise in summer. Now as we tend to already mentioned as most of the work was dispensed to judge the performance of the EATHE in steady state condition. and a few of the researchers mentioned the deterioration beneath transient condition in thermal performance ofEATHE, however no scientist drawn attention toward the impact of wet content gift within the soil that helps within the higher heat transfer. because the performance of EATHE deteriorate thanks to the continual operation of the system. The wet content within the soil is ablated because the hot air exchanges its heat with earth temperature once it comes connected with underground buried pipes. Analysis of this wet content in soil helps North American country to spot higher performance of EATHE. a number of the researchers additionally studies concerning role of soil thermal conduction within the analysis of performance of EATHE. the upper soil thermal conduction results into higher thermal performance of EATHE system even longer amount of operation. Many labours are needed to try to within the direction of continuous operation of EATHE beneath transient condition and the way it will be maintain smart heat transfer beneath longer use of earth air device.

Mahendra Kumar Verma ,VikasBansalaetal(2016) reported that Solar chimney and earth air pipe device area unit the new approach to scale back the cooling load by means that of passive ventilation and cooling which needs low energy to run the system. it had been found that integrated system beside EAPHE offers additional satisfactory results. If star chimney will be used for optimum result, it reduces the electrical consumption by 10-20%. star chimney will be used at the hours of darkness by putting in rotary engine at the outlet of star chimney to charge the battery. Performance of integrated ECC system will be increased by increasing the evaporation rate of water which will be achieved by adding some additives. it had been found that EAPHE is that the unremarkably used strategies for cooling of heating functions. Literature review shows that temperature drop up to 12.6°C will be achieved and energy consumption gets reduced by eighteen percentage plus air cooled condenser of 1.5TR window AC.

Suresh Kumar Soni, Mukesh Pandey &Vishvendra Nath Bartaria(2016) reported that GCHE (Group Coupled Heat Exchanger) systems are recognized to be outstanding in house

heating/cooling and are wide used for years. From the literature review, it's ascertained that neither GCHE nor passive technologies alone ar satisfactory in majority of the cases. The desired resolution seems to be rising within the combination ofGCHE and passive systems. Review of hybrid GCHE systems over that hybrid of EAHE with cooling may increase cooling result by 69% andreduce length of buried pipe up to 93.5%. EAHE with PCM increased the cooling result up to 47% as compared to traditional air-con system. additionally, GSHP (Ground source heat pump) with state change cooling system or so doubled the COP. Therefore, to mitigate CO_2 emission and scale back energy consumption, environmentally clean and energy economical hybrid GCHE systems may be thought of as another to the mechanical vapour compression systems. Hybridsystem might scale back vital quantity of power consumption. DX-GSHP (Direct Exchange Geothermal Heat Pump) with typical air con system could scale back power consumption by fifteen.5%. EAHE with typical air con system might scale back power consumption by 18.1% by supply underground cooled air to cool down condenser coil of cooling system. the area of hybrid GCHE systems

D.G. Leo Samuel, S.M. Shiva Nagendra (2013) presented a review paper on passive alternatives to mechanical air conditioning of buildings is administered. Passive cooling systems square measure viable alternatives to energy intensive mechanical cooling systems. Passive cooling systems square measure eco-friendly and supply comfortable surroundings. However, they cannot cut back humidity. Passive cooling systems square measure dynamic systems: their performance fluctuates with time of day and seasons, with few exceptions(deep ocean/lake cooling). Numerous modelling procedures square measure accessible to check the performance and style of passive cooling systems. Designing of passive cooling systems is very captivated with site characteristics.

Ashish Kumar Chaturved and V N Bartaria (2015) found in thier research thatexperimental setup is associate degree open loop flow system has been designed and fictional to conduct experimental investigation on the temperature distinction for water and Outlet section, heat transfer, constant of performance and fluid flow characteristics ofa pipe in parallel affiliation. The experimental data are favourable to the rise of cooling rate for the summer (May 2014)condition, and heating rate of winter(November 2014) condition heat transfercoefficient.The Earth Tube Device TakenOne horizontal pipe of 50mminner diameterwith total length of 9 m. 3 pipe everylength of 3m is connected nonparallelconnection, created from GI pipes, and buriedat a depth of three m in an exceedingly flat land with dry soil. The Series affiliation of GI pipes exhaust manifold for air duct. close air wassucked through the pipe by suggests that of acentrifugal blower by a a pair of part, 0.25 hp, 230V and 2800 rev motor. The blower is employed to suck the new close air through thepipelines and delivered the cool air for required place in Summer (May 2014)climate and hot air needed place in winter. Tarun Gehlot etal(2019) reported that chloride penetration is ingress of chloride ions into the concrete and destroying the passivating layer encompassing the reinforcement leading to its corrosion.

3 SUMMARY OF LITERATURE REVIEW

EAHE systems offer reductions in heating/cooling load of buildings, power consumption, CFC and HCFC consumption and greenhouse gas emissions, and have been extensively used for years. Generally, the thermal performance of the EAHE system increases with the increaseof pipeburied length and depth, while the performance decreases with the increaseof pipe diameter and air velocity.

- The soil surrounding the pipe is isotropic with uniform thermal conductivity in all layers.
- The thermal resistance of the pipe material is negligible (the thickness of the pipe is very small .The pipe is a uniform circular cross section.
- The surface temperature of the floor is similar to the temperature of the ambient air, which is the same as the inlet air temperature.
- If the distance `r` from the outer surface of the pipe is exceeded, the thermal effect of the soil surrounding the pipe is negligible. where `r` is the radius of the pipe.
- The diffusion of moisture from the soil to the air flowing through the buried pipe is negligible.

Numerical and analytical observations have created a series of research gaps from the literature review. Therefore,the analysis provides some gaps in the investigation. Followings are some fundamental issues that published literature does not discussed significantly.

- Literature review suggest that most of work on geothermal exchanger done on straight tube channels so there is wide scope of using spiral or helical tube heat exchangers and other tube arrangement.
- The material and cross section of the heat exchange tube can also produce important effects.
- The use of EAHE alone cannot provide the thermal comfort of cooling. Consequently, it can reduce the electric power consumption like using the means of air conditioning.
- in order that, the flowing air preserves its cool most possible in the vertical portion it must be ensure sufficient conditions of thermal insulation in this portion
- the continuous operation mode does not affect the thermal performances and outlet air temperature of the EAHE during all 71 h of operating for high soil thermal conductivities and low air flow velocities
- the initial 30 m of the pipe provides almost 78% of the total air temperature drop.
- It has been observed from a large number of studies that as the pipe diameter increases, the total temperature drop/temperature rise in the EATHE pipe decreases, but for a given flow rate, the overall heat transfer rate increases. For the same resistance, the cost of a large diameter pipe (0.15 m) is 6 to 7 times higher than the cost of a small diameter pipe (0.05 m).

Knowledge of soil thermophysical properties is crucial to the design of the EATHE system. By providing soil with good thermal conductivity and higher moisture content near the EATHE pipeline, improved performance of the EATHE system can be obtained. The

air velocity also plays a vital role in the design of the EATHE system. As the air velocity decreases, the total increase/decrease of the air temperature increases, but the heating/cooling capacity of the EATHE system decreases, and vice versa. Therefore, the airflow must be optimized for the specific application.

However, when using multiple pipes, when EATHE operates continuously for longer periods of time under adverse environmental conditions, the spacing between the pipes becomes a key parameter. Note that the thickness of the heat affected zone (TIZ) does not remain constant along the EATHE pipe because the rate of heat transfer in the upstream section of the pipe is higher than in the downstream section. Therefore, it is recommended that the distance between the pipes should be reduced gradually along the length of pipe. This consideration will be reduce overall excavation and backfilling costs. The depth of EATHE pipe should be kept between 3 m and 4 m because too deeper excavation of soil does not result in any appreciable change in soil temperature. Instead, it only increases the trenching cost and challenges the economic viability of EATHE. It should be noted that the operating duration of the EATHE system must be properly managedso that the soil can at least recover its thermal properties to a considerable extent when used for a long periodof time. The intermittent operation is preferable than the continuous operation. Hence, it is recommended that EATHE should be used during daytime in summer and during night time in winter season Therefore, it is concluded that if the EATHE system is developed according to theproper design guidelines, it will be able to provide adequate heating and cooling for small and large buildings and save energy significantly.

4 **CONCLUSIONS**

It can be concluded that the effective use of EAHE system combined with sustainable energy and latest technology will play an important role in saving energy consumption and environment not only in India but also in the world. From this perspective,the author hopes that this review article will be very useful for researchers and scientists in the field of passive heating / cooling of buildings who mainly use EAHE systems Implementation of earth air heat exchangers for partial or complete cooling and heating of ventilating air in facilities has been with varying success. Unfortunately, there are many overgeneralizations in the literature about the applicability of these systems, both for and against. At a depth of about 1.5 to 2 m, the soil temperature remains almost constant. This constant temperature is called theunchanged temperature of the earth. The earth's undisturbed temperature remains always higher than that of ambient air temperature in winter and vice versa in summer. In order toeffectively utilize the heat capacity of the earth,the EAHE system will be designed. If theachieved cooling or heating is insufficient, the EAHE outlet can be connected to a conventional air conditioning unit. The use of green and clean energy to minimize CFC emissions and minimize traditional energy consumption is a major concernaroundthe world.

The EAHE system can heat different types of buildings in winter by preheating air and vice versa,thus playing an important role inminimizing energy consumption.

Therefore, design optimization, modelling and testing of EAHE systems is very essential. Several calculation models havebeen foundin the literature to simulate the thermophysical behavior of ground-air heat exchangers. A well designed EAHE can reduce electricity consumption of a typical house by 30%An important aspect of earth air heat exchangers takes into account the passive nature of their operation and the wide variability of natural system conditions. The temperature drop in the upstream section of the pipe was sharp and then turnedmild. As the air flow increases, the outlet temperature also increases. The results also show that conduction plays a very important role in air cooling, whichcan be clearly seen from the fact that the temperature at which the insulation is completed remains constant. Tube length is independent parameter influence on pressure drop. Diameter and velocity have combined influence on pressure drop. For the same diameter, a higherspeed willresult in a higher pressure drop. At higher outlet speeds and maximum temperature differences, the system hasthe highest operating efficiency. Results are also improved when the earth air tunnel heat exchanger is coupled with air conditioner which implies the increases in the COP (Coefficient of performance) of the system. This study reviews various parameters thataffect the performance of the EATHE system. It is recommended to use EATHE in placeswith largechanges in day and night and seasonal ambient temperature, because if the ambient air temperature changes slightly(lessthan7-8°C), poor performance of EATHE is observed. Therefore, the intake air temperature has a significant impact on the thermal performance of the EATHE system.

Declaration of competing interest: The authors proclaim that they have no any conflict of interest.

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