# Earth Tube Heat Exchanger: An Energy-Efficient Solution for Building Ventilation

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***Abstract— The Earth Tube Heat Exchanger (ETHE) is a passive cooling and heating technology that exchanges heat between the air and the earth through a buried pipe system. ETHE is an environmentally friendly and energy-efficient solution for building ventilation, as it does not rely on mechanical systems or electricity to operate. This paper provides an overview of recent research on ETHE systems, focusing on design aspects, thermal performance, and material selection. The paper also highlights the latest advancements in ETHE technology, including improved materials, automated control systems, geothermal earth tubes, hybrid systems, and improved design.***

***Keywords— HVAC, ETHE, Applications.***

## I INTRODUCTION

An ETHE, often referred to as a ground-coupled heat exchanger or an earth-air heat exchanger, is a kind of passive ventilation system that can be used to cool or heat a building by exchanging heat with the ground [1]. A few feet of subterranean pipes or a network of pipes make up the system's conventional design. Before being pumped inside the building, air is sucked into the pipes and heated or cooled by the surrounding earth. The system can supply a source of cool air to the building in the summer since the soil around the pipes is frequently cooler than the surrounding air. The system can offer a source of pre-heated air throughout the winter, which is the opposite of the summer

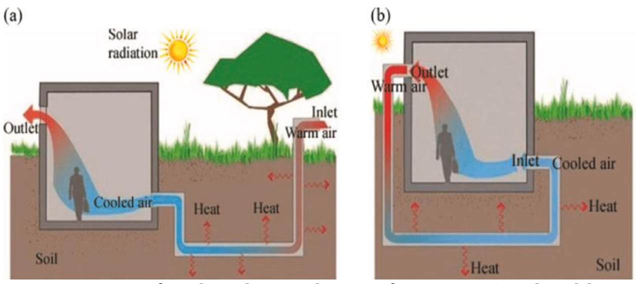


Fig. 1 Varieties of earth-air heat exchangers for summer (a) Closed-loop system (b) Open-loop system [6]

As they are not powered by mechanical or electrical systems, earth tube heat exchangers are typically seen as an energy- and environmentally-friendly option for building ventilation. However, when developing and installing the system, it's crucial to take site-specific variables into account because they can have an impact on the system's effectiveness [3]. Due to its potential to lower energy use and carbon emissions in buildings, the earth tube heat exchanger (ETHE) is a passive cooling and heating technology that has attracted a lot of interest. Through a network of subterranean pipes, ETHE transfers heat from the air to the ground. To comprehend its functionality and improve its design, this technology has undergone substantial research in recent years [4]. A thorough analysis of the effectiveness of ETHE in cooling applications was carried out by [1]. Innovative building technologies have been created in response to the growing need for sustainable and energy-efficient buildings. Earth Air Heat Exchangers (EAHEs) are one such device that can be used to warm or cool the air entering a building by exchanging heat with the earth. Recent research has concentrated on this technology, leading to considerable improvements in EAHE system design and implementation [5, 6].

## II. EARTH TUBE HEAT EXCHANGER DESIGN

For Earth Tube Heat Exchangers (ETHE) to work at their best, their design is essential. The depth and position of the subterranean trenches, the size and length of the tubes, the material used to build them, and the local climate must all be taken into account during the design phase. An energy-efficient technique known as an earth tube heat exchanger (ETHE) uses the thermal characteristics of the earth to either cool or heat ventilation air in buildings. In a variety of climates, ETHE systems are growing in popularity because of their many benefits, including lower energy use, less upkeep, and better indoor air quality. a summary of current research on ETHE systems with an emphasis on design, thermal performance, and material choice.

### *A Design Aspects*

[7] Carried out a research project to examine the impact of various pipe design features for earth-air tunnel heat exchanger systems. According to the study, the thermal performance of ETHE systems is substantially impacted by the diameter, length, and shape of the pipes. Similar to this, [8] examined the utilisation of large diameter earth tubes in cold areas and discovered that tube diameter plays a crucial role in determining the effectiveness of ETHE systems.

### *C Thermal Performance*

A parametric investigation on the thermal efficiency of earth-to-air heat exchangers employed for building cooling was conducted [9]. According to the study, the thermal efficiency of the ETHE system is greatly influenced by the heat transfer coefficient and the temperature of the input air. A review research was carried out by [10] to look into how material affected the thermal performance of ETHE systems.

*D Innovative Approaches*

Water finned tubes were suggested as a way to enhance the performance of ETHE systems by [11]. The effectiveness of the system with and without water finned tubes was assessed using a theoretical method in the study. Furthermore, [12] carried out a study to evaluate an ETHE system's transient performance in warm climate circumstances.

## III. APPLICATIONS OF EARTH TUBE HEAT EXCHANGER

Earth-to-air heat exchangers (EAHEs) have a wide range of applications in various sectors such as residential, commercial, industrial, and agricultural buildings. One of the most significant applications of EAHEs is for space heating and cooling in buildings. The system can be used to preheat or precool the incoming air to the building, thus reducing the load on the heating and cooling systems.
Another application of EAHEs is in greenhouses and other agricultural facilities. The system can be used to cool or dehumidify the incoming air, creating a more favorable environment for plant growth. Additionally, EAHEs can be used for ventilation in mines, providing fresh air to miners working underground.

EAHEs can also be utilized in air conditioning systems for data centers, where cooling is essential to prevent overheating and ensure optimal performance of equipment. Moreover, they can be used in industrial processes that require heating or cooling, such as drying or cooling processes. EAHEs can also be applied in regions with high humidity, such as tropical and subtropical areas. In these regions, the EAHE can be used to dehumidify the incoming air, reducing the load on the air conditioning system and improving indoor air quality.
They are most commonly used for heating and cooling of the ventilation air, but can also be utilized for space heating and cooling.

*A* Ventilation Air Heating and Cooling One of the most common applications of earth tube heat exchangers is the heating and cooling of the ventilation air. The tubes are buried underground, where the temperature remains relatively constant throughout the year. The air that is drawn through the tubes is either warmed or cooled, depending on the season, before it enters the building. This reduces the load on the HVAC system, resulting in energy savings.

*B* Space Heating and Cooling Earth tube heat exchangers can also be used for space heating and cooling. In this application, the tubes are buried deeper in the ground, where the temperature is more stable. Heat is extracted from the ground during the winter and transferred to the building, while heat is extracted from the building during the summer and transferred to the ground.

*C* Greenhouses and Agriculture Earth tube heat exchangers can be used in greenhouses and other agricultural settings to control the temperature and humidity. They can be used for both heating and cooling, depending on the needs of the plants. By utilizing the constant temperature of the ground, energy costs can be reduced, and crop yields can be increased.

*D* Industrial Applications Earth tube heat exchangers can also be used in industrial applications, such as cooling of process air, heat recovery from exhaust air, and cooling of machinery. They can be customized to meet the specific needs of each application, resulting in increased energy efficiency and reduced operating costs.

## IV LATEST ADVANCEMENTS IN EARTH TUBE HEAT EXCHANGER TECHNOLOGY

Earth tube heat exchanger (ETHE) technology has undergone significant advancements in recent years, driven by the need for more efficient and sustainable heating and cooling solutions. Here are some of the latest advancements in ETHE technology:

Improved Materials: The longevity and longevity of ETHE systems have grown thanks to the introduction of high-performance substances like cross-linked polyethylene (PEX) and high-density polyethylene (HDPE). According to the research presented in [13], adding backfill made of thermal insulation materials like perlite & vermiculite can greatly enhance the EAHE's thermal efficiency, with heat exchange rates rising by as much as 70%. An annular phase change material (PCM) was merged with a vertical earth-to-air heat exchanger system, and [14] set out to explore how well it performed. According to the study, the ideal quantity of PCM needed for the system was 60% by volume, and the ideal depth for the PCM was 4 metres below the ground's surface. These substances are appropriate for use in ETHE systems because they can survive harsh conditions in the outdoors and are corrosion-resistant.

Automated Control Systems: The integration of automated control systems in ETHE systems has increased their efficiency and effectiveness. These systems use sensors and controllers to monitor temperature and humidity levels and adjust the flow of air through the ETHE system accordingly. [15] Conducted a review of data-driven modelling techniques for EAHEs. The review also covered the use of experimental data to develop machine learning models, the integration of weather forecasting models with EAHE performance models, and the use of optimization algorithms to improve the performance of EAHEs. [16] Proposes a control method for a heat exchanger using a fuzzy fractional-order proportional-integral-derivative (PID) controller. The proposed method uses a fuzzy logic system to adjust the gains of the PID controller, which in turn adjusts the flow rate of the working fluid in the heat exchanger to maintain the desired temperature. The fractional-order approach is used to improve the system's transient response and tracking performance.

Geothermal Earth Tubes: The earth's constant temperature is used by geothermal earth tubes to warm and cool the air moving through the ETHE system. They can drastically lower the price of cooling and heating and can be employed in residential as well as business structures. An improved cooling system that incorporates a multi-geothermal approach is presented by [17]. The study's objective is to examine the performance and viability of a cooling system that makes use of a number of geothermal heat exchangers (GHEs) and an air-cooled chiller. The system was created for a residential structure situated in a hot, muggy environment. The coefficient of performance (COP) of the system was 7.2, which is significantly greater than the COP of an ordinary air-cooled chiller. Geothermal energy may be used to enhance the cooling of a farming greenhouse in a desert climate, according to [18]. The study employed a numerical simulation methodology to assess the effectiveness of a geothermal system made up of a heat pump and a horizontal ground heat exchanger. According to the findings, the technology might lower the greenhouse's temperature by up to 11.7 °C in comparison to the outside air, which could improve crop productivity and cut down on energy use.

Hybrid Systems: Earth tube heat exchangers are added to conventional heating and cooling systems in hybrid ETHE systems to boost efficiency and lessen the negative environmental effects. These technologies can dramatically lower energy usage and are applicable to both residential and commercial buildings. Building integrated photovoltaic/thermal (BIPV/T), earth-air heat exchanger (EAHE), and a hybrid system combining BIPV/T and EAHE are three distinct systems for a residential building that [19] analyses for effectiveness. The findings indicate that the EAHE system has the smallest impact on the environment and price, whereas the hybrid system has the maximum energy and exergy efficiency. For the ventilation and heating/cooling of buildings, [20] suggests a brand-new hybrid system that brings together the benefits of wind catchers as well as ground source heat pumps (GSHPs). Although the GSHP system supplies the essential heating and cooling, the wind catcher, a conventional passive ventilation system, is employed to offer natural ventilation. The findings demonstrate that the suggested hybrid system can improve indoor air quality and comfort while cutting the GSHP system's energy usage by up to 30%.

Improved Design: Design improvements have produced ETHE systems that are more effective and efficient. For instance, it has been discovered that using vertical ETHE systems rather than horizontal ones can boost their efficiency by up to 50%. A research investigation on the improvement of a multi-pipe earth to air heat exchanger (EPHX) in a greenhouse, that is employed to cool and dehumidify the air inside the greenhouse, is presented by [21]. The study's objectives are to decrease the greenhouse's energy use and increase the EPHX's heat exchange efficiency. The authors suggested an improved EPHX design based on the results of the simulation that uses less energy and achieves a greater heat exchange efficiency than the original design. The optimized EPHX has a 12-layer pipe configuration with a pipe diameter of 25 mm and a spacing of 120 mm.

## V CONCLUSION

Earth Tube Heat Exchangers (ETHE) offer several advantages, such as reduced energy consumption, low maintenance, and improved indoor air quality. With the increasing demand for sustainable and energy-efficient buildings, ETHE technology has undergone significant advancements in recent years. The latest advancements in ETHE technology, such as improved materials, automated control systems, geothermal earth tubes, hybrid systems, and improved design, have the potential to make ETHE systems even more efficient and cost-effective. It is important to consider site-specific conditions when designing and installing ETHE systems to ensure their optimal performance. Overall, ETHE systems are an excellent solution for building ventilation and have a promising future in the construction industry.

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