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Fabrication and analysis of an ETHE by using CFD

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Abstract: This project encompasses the fabrication and Computational Fluid Dynamics (CFD) analysis of an Earth Tube Heat Exchanger (ETHE) designed to enhance energy efficiency in HVAC systems for sustainable buildings. The ETHE system leverages the stable underground temperature to precondition incoming air, thereby reducing the load on conventional heating, ventilation, and air conditioning (HVAC) systems. The fabrication process involves constructing a prototype ETHE system using environmentally friendly materials such as high-density polyethylene (HDPE) tubing and a heat exchanger core. This project contributes to the knowledge base on sustainable HVAC technologies, specifically focusing on Earth Tube Heat Exchangers. The combination of fabrication and CFD analysis offers a comprehensive understanding of the system's thermal performance, presenting a promising solution for reducing energy consumption in buildings while ensuring occupant comfort and indoor air quality. The study sets the stage for integrating Earth Tube Heat Exchangers into mainstream HVAC systems, promoting sustainable and energy-efficient building designs.

KEYWORDS: Earth tube heat exchanger, HVAC systems, CFD analysis, High-density polyethylene.

INTRODUCTION:

In the quest for sustainable energy solutions, Earth Tube Heat Exchangers (ETHEs) have emerged as a promising technology for passive cooling and heating of buildings. By harnessing the stable temperature of the earth below the surface, these systems offer efficient and environmentally friendly thermal management. Computational Fluid Dynamics (CFD) has become an indispensable tool in optimizing the design and performance of such systems.

The Earth Tube Heat Exchanger operates on the principle of utilizing the earth's relatively constant temperature to pre-condition the air entering a building. In its simplest form, it consists of a network of buried tubes through which air is circulated. As the air passes through these tubes, it exchanges heat with the surrounding earth, either gaining or losing thermal energy depending on the season and the desired indoor conditions.

The fabrication of an Earth Tube Heat Exchanger involves careful consideration of various factors, including the selection of materials, tube diameter, length, and burial depth. The layout of the tubes should be optimized to maximize heat exchange while minimizing pressure drop and energy consumption. Additionally, proper insulation and sealing are crucial to prevent heat loss or gain from the surrounding soil.

CFD plays a vital role in the analysis and optimization of Earth Tube Heat Exchangers. By simulating the fluid flow and heat transfer within the underground tubes, CFD allows engineers to evaluate different design configurations and operating conditions virtually. This enables rapid prototyping and iteration, reducing the need for costly and time-consuming physical experiments.

Key parameters studied using CFD include airflow velocity, temperature distribution, heat transfer rates, and pressure drop along the length of the tubes. Through sensitivity analyses and parametric studies, engineers can identify optimal design parameters to achieve desired performance metrics such as energy efficiency and thermal comfort.

Furthermore, CFD facilitates the assessment of potential challenges and limitations associated with Earth Tube Heat Exchangers, such as the risk of condensation, air stagnation, and soil thermal properties variations. By integrating advanced modelling techniques, such as multiphase flow and transient simulations, engineers can gain deeper insights into the dynamic behaviour of these systems under different environmental conditions.

In this project, we present a comprehensive investigation into the fabrication and analysis of an Earth Tube Heat Exchanger using CFD. Through a combination of theoretical modelling, numerical simulations, and experimental validation, we aim to provide valuable insights into the design, performance, and practical implementation of this sustainable technology for building HVAC applications.

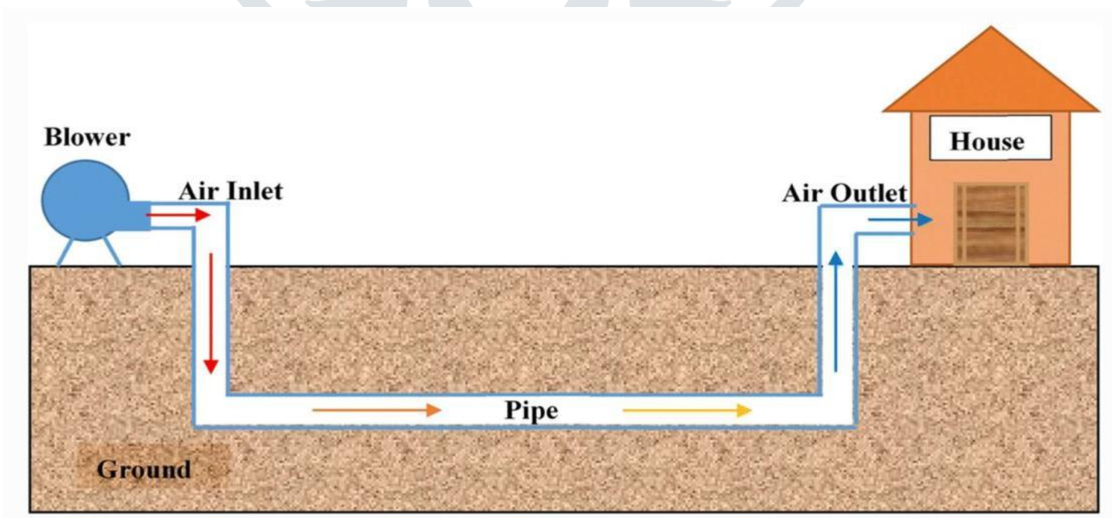

Fig : Overview of ETHE System

II. MATERIALS & METHODOLOGY:

MATERIALS:

- **HDPE Pipe**
- **Blower**
- **Thermostats**

HDPE Pipe:

High-Density Polyethylene (HDPE) pipes are prized for their exceptional properties and advantages. Offering high tensile strength and flexibility, HDPE pipes are ideal for underground installations and water distribution systems, easily navigating obstacles without additional fittings. They boast remarkable chemical resistance, enduring corrosion and abrasion, ensuring longevity exceeding 50 years with proper maintenance. Lightweight and resistant to biological growth, they are environmentally sustainable and cost-effective, reducing labor and

equipment expenses. With smooth inner surfaces reducing friction, HDPE pipes promote efficient fluid flow, saving energy and enhancing hydraulic performance. Leak-free joints, facilitated by heat fusion or mechanical fittings, ensure reliable connections, minimizing water loss and contamination risks. Recyclable and manufactured from recycled materials, HDPE pipes exemplify environmental responsibility while providing a durable and versatile solution for water supply, wastewater management, and industrial applications.

Types of Pipes used for ETHE System:

1. HDPE (High-Density Polyethylene):

Description: HDPE pipes are known for their flexibility, durability, and resistance to corrosion and chemicals. They have smooth interiors that reduce friction and allow for efficient airflow.

Fig- HDPE Pipe

Blower:

A blower is a mechanical device designed to generate a high-velocity airflow by rapidly rotating blades or impellers within an enclosed housing. Typically used for ventilation, cooling, or conveying purposes, blowers efficiently move air or gas from one location to another. They come in various configurations, including centrifugal and axial types, each with distinct airflow characteristics and performance capabilities. In industrial and commercial settings, blowers are integral components of HVAC systems, air pollution control systems, pneumatic conveying systems, and more.

3

Fig-3.9 Blower

A variable speed control blower is a versatile airflow system equipped with adjustable mechanisms allowing users to regulate the speed of air movement. Unlike fixed-speed blowers, which operate at a constant rate, these blowers offer flexibility through electronic controls that modulate the power supplied to the motor, thus controlling its rotational speed. Widely used in HVAC systems, industrial ventilation, air purification, and automotive cooling, they enable precise airflow management for various applications. Featuring digital control interfaces, remote capabilities, and programmable settings, they offer convenience and adaptability. Incorporating sensors and feedback mechanisms, they dynamically adjust speed based on environmental conditions or system requirements. The ability to vary airflow provides benefits including enhanced comfort, energy efficiency, quieter operation, and prolonged equipment lifespan. In summary, variable speed control blowers offer an efficient and adaptable solution for diverse airflow needs, making them invaluable in optimizing air quality, temperature control, and energy consumption across different sectors and applications.

Digital Thermostat with LCD Display:

Description: A digital thermostat with an LCD display offers precise temperature control and user-friendly interface. It typically allows programming of temperature settings for different times of the day, providing flexibility and energy savings.

Fig : Digital thermostat with LCD

METHODOLOGY:

Developing a ETHE system with the help of different parameters and different materials by using CFD (Computational Fluid Dynamics) simulation setup with the help of ANSYS WORKBENCH.

The air supply module in the proposed model of Earth Tube Heat Exchanger (ETHE) fabrication and analysis using Computational Fluid Dynamics (CFD) is pivotal for delivering ambient air to the underground earth tubes. Comprised of components like Variable speed control blower, it ensures a continuous airflow essential for efficient heat exchange with the surrounding soil. Blower selection considers factors like efficiency, noise levels, and reliability to achieve desired airflow rates. Pipe design focuses on efficient distribution while minimizing pressure losses through proper sizing, layout, and insulation. Integrated control systems regulate module operation based on user-defined parameters and sensor feedback, optimizing performance and energy efficiency. The module's inclusion in the CFD model facilitates simulation of airflow distribution and pressure drop, aiding in optimizing pipe design, blower selection, and control strategies. Experimental validation verifies module performance under real-world conditions, guiding iterative optimization to enhance efficiency, reliability, and energy consumption. Thus, the air supply module is integral to the overall effectiveness and efficiency of the ETHE system.

And we consider HDPE Pipe as a material of buried pipe. And High-Density Polyethylene (HDPE) pipes are prized for their exceptional properties and advantages. Offering high tensile strength and flexibility, HDPE pipes are ideal for underground installations and water distribution systems, easily navigating obstacles without additional fittings. They boast remarkable chemical resistance, enduring corrosion and abrasion, ensuring longevity exceeding 50 years with proper maintenance. Lightweight and resistant to biological growth, they are environmentally sustainable and cost-effective, reducing labor and equipment expenses. With smooth inner surfaces reducing friction, HDPE pipes promote

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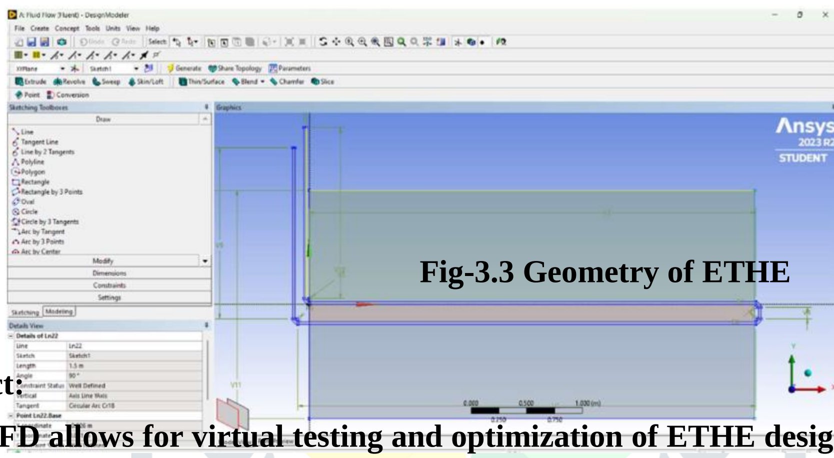

Fig-3.3 Geometry of ETHE

Benefits Of Project:

1.Cost Savings: CFD allows for virtual testing and optimization of ETHE designs, reducing the need for physical prototypes and associated fabrication costs.

2.Enhanced Performance Prediction: CFD provides detailed insights into the airflow patterns, heat transfer, and temperature distribution within the ETHE, enabling accurate prediction of its performance under various conditions.

3.Optimization of Design Parameters: CFD analysis helps in optimizing the geometric parameters of the ETHE, such as tube diameter, length, and spacing, to maximize heat transfer efficiency and minimize pressure drop.

4. Time Efficiency: CFD simulations enable rapid evaluation of multiple design iterations, reducing the time required for design optimization and development.

5.Risk Reduction: Virtual analysis with CFD helps identify potential design flaws or performance issues early in the development process, reducing the risk of costly errors during fabrication and operation.

6.Flexibility in Testing Conditions: CFD allows for testing ETHE performance under different environmental conditions, airflow rates, and soil properties, providing valuable insights for real-world applications.

7. Insightful Visualization: Visualization tools in CFD software enable intuitive understanding of airflow patterns and temperature distributions within the ETHE, facilitating effective design decisions.

8.Improved Energy Efficiency: By optimizing the ETHE design using CFD, energy consumption can be minimized, leading to improved energy efficiency and reduced operational costs.

So, there you have it! These are some of the benefits of using Earth tube heat exchanger. It saves you time and effort, reduces costs, and contributes to a greener environment. It's a smart and convenient way to keep your area well-maintained.

III. CONCLUSION

Through theoretical calculations, numerical simulations, and sensitivity analyses, optimal design parameters such as tube length, diameter, material selection, and airflow velocity were identified. The analysis revealed that longer tubes with higher thermal conductivity materials such as HDPE are more effective in achieving significant temperature drops while minimizing pressure drop within the system. By optimizing design parameters and airflow velocities, significant improvements in heat transfer efficiency were achieved, leading to enhanced energy savings and environmental sustainability.

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