IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 5, Issue 1, May 2025

Impact Factor: 7.67

Smart Earth Soil to Air Heat Exchanger

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Abstract: *Conventional soil-to-air heat exchangers (SAHX) leverage the stable ground temperature for pre-heating or pre-cooling ventilation air. However, their performance can be limited by factors like static control strategies and a lack of real-time environmental data. This project proposes a novel approach for a smart and data-driven SAHX system. The proposed system integrates sensor technology for monitoring soil temperature, air temperature, humidity, and potentially soil moisture. This real-time data will be used to train and implement machine learning models for predicting heat transfer efficiency. The model's insights will be utilized by a control system to dynamically adjust airflow rates, fan operation, or other control parameters for optimal performance. This project aims to develop a prototype SAHX system with the following key features: Sensor Integration: Utilize sensors to capture real-time environmental data. Data Driven Optimization: Train machine learning models to predict heat transfer efficiency based on sensor data. Adaptive Control System: Implement a control system that utilizes model predictions to dynamically optimize airflow and heat trans fer. The successful implementation of this project has the potential to significantly improve the efficiency of SAHX systems. By leveraging data-driven insights and adaptive control, the system can optimize thermal comfort while minimizing energy consumption in buildings.*

Keywords: Smart Soil-to-Air Heat Exchanger, Smart power management, Soil to air exchanger, SAHX system

I. INTRODUCTION

1. Project Background: Traditional SAHX systems offer energy savings but lack real-time data for optimal performance. Our project creates a smart SAHX that uses sensors and machine learning to predict heat transfer and dynamically adjust settings. This data-driven approach optimizes comfort and minimizes energy use, paving the way for a new era of sustainable building technology

2. Eco-Friendly Materials: Use recycled or bio-based materials for the SAHX unit to minimize manufacturing footprint. Renewable Energy Fans: Power the SAHX with low-power fans driven by solar panels (where possible) for a clean energy source. Smart Power Management: Automatically adjust fan operation based on real-time data to cut unnecessary energy use.

3. The smart SAHX leverages sensor technology. Temperature sensors within the soil and air passage will monitor thermal conditions. Humidity sensors track moisture content for optimal heat transfer and condensation prevention. A central unit like Ar duino or Raspberry Pi collects this data and communicates with the control system. Machine learning models, trained on historical data, predict heat transfer efficiency. The control system then translates these predictions into actions, adjusting fan speed, dampers, or other parameters for optimized performance. This data-driven approach ensures real-time adjustments for maximum comfort and minimal energy use.

4. Technical feasibility: Leveraging the Earth's stable soil temperature, this project proposes a novel smart soil-to-air heat exchanger (SAHX). By integrating sensors and machine learning, the system will optimize heat transfer in real-time, leading to improved thermal comfort in buildings while minimizing energy consumption. This data-driven approach promotes sustainability and paves the way for a new generation of eco-friendly building technology

DOI: 10.48175/568

II. LITERATURE REVIEW

The use of the earth as a heat source or as a heat sink, which, in combination with buried tubes, can serve as a direct heat exchanger, is an old concept that has existed in Persian architecture for centuries [Trombe et al, 1994]. In literature, the system is usually called Earth-to-air heat exchanger(s) (ETAHE or EAHXs) [Tzferis et al, 1992; Mihalakakou et al, 1994 and 1996b; Santamouris et al, 1995a; Bojic et al, 1999; Nara et al, 2000; Gieseler et al, 2002; De Paepe et al, 2003; Pfafferott, 2003]. But it is also called: 1. Buried pipe system [Hollmuller et al 2003b; Mihalakakou et al, 1995, 1996a and 2003] 2. Hypocaust [Hollmuller et al, 2003a] 4. Air-to-earth heat exchanger (ATE) [Trombe et al, 1994; Bojic et al, 1997] 6. Underground air tunnel [Goswami et al, 1985 and 1990] 7. Earth-tube heat exchanger [Gustafsson, 1993; Bourret et al, 1994; Lemay et al, 1994 and 1995; Dhia, 1995; Levit et al, 1989] 8. Air-soil heat exchanger [Hollmuller, 2003a] 9. Earth air tunnel [Bansal et al, 1986; Arzano et al, 1994; Kaushik et al, 1994; Kumar et al, 2003] Throughout the thesis, the term of Earth-to-air heat exchanger (ETAHE) is employed. 2.2 ETAHE applications All over the world, this technique is implemented 4in a variety of buildings (see Table 2. 1.). But most of them are in European countries [Hokkaner, 1994; Mihalakakou et al, 1996a; Wagner et al, 2000 and De Paepe et al, 2001]. Many ETAHE systems have been applied to greenhouses [Mavroyanopoulos et al, 1986; Boulard et al, 1989; Levit et al, 1989; Santamouris et al, 1994 and 1995b; Sutar et al, 1996; Gauthier et al, 1997; Tiwari et al, 1998 and Nara et al, 2000], and live stock houses [Lemay et al, 1994 and 1995; Shingari, 1995; Dhia, 1995]. For livestock housing latent and sensible heat production is very high due to the high concentration of animals in the building. To maintain animal health, and consequently to improve the efficiency of animal production, ventilation requirements are such important that it is necessary to keep a high value of air flow rate. Correia et al [2001] studied a livestock building with ETAHEs and a solar chimney and made a conclusion that the thermal environment inside the building stays about 91Recently, more and more ETAHE systems found them applied not only in residential buildings [Bowman et al, 1987; Arzano et al, 1994] but also commercial and institutional buildings. In literature reports applications included a hospital complex [Sodha et al, 1985], university buildings [Melіß et al, 2000; Athienitis et al., 2002], a cinema hall [Singh et al, 1996], etc. All of these reports demonstrate that the ETAHE technique has a promising contribution to reducing cooling and heating loads. In Canada, there are only two ETAHE applications identified in various publications. One is a greenhouse [Santamouris et al, 1995b], while the other is a growing-finishing swine building [Lemay, 1994 and 1995]. They are all in Quebec. Right now, the Cite du Cirque with ETAHE system in Montreal is under construction. This project opens a new era that this technology begins to be employed on a wider scale in Canada. 2.3 Review of models The various models are summarized and detailed in Table 2.3. 293.1 Multi-dimensional models To predict the performance of the ETAHE system, Mihalakakou et al [1994], Bojic et al. [1997], Gauthier et al [1997] and Hollmuller et al [2003b] have developed some complete and dynamic models for ETAHEs. These models differ in the way the geometry is described (2D, 3D, polar coordinates) and in the way the effects of moisture transport in the ground and in the air are accounted for. However, these calculation methods are quite complex and their solutions are usually obtained by using commercial software such as TRNSYS, ANSYS, SMILE and FLUENT etc. Therefore, the applicability for design is limited to people who 5are able to use the calculation codes or software. They are mainly used to show that the ETAHE is a promising and effective technology. The heat transfer model is based on the following assumptions: 1. Conduction heat transfer is transient and fully three dimensional in the soil. 2. The thermophysical properties of the soil and other materials are constant. 3. Heat transfer by moisture gradients in the soil is neglected. 4. Heat transfer in the tube is dominated by convection. It is coupled with the temperature field of the surrounding soil by the boundary conditions at the tube surface. 2.3.2 One-dimensional models In the literature several one-dimensional calculation models for ETAHEs are found. Tzaferis et al. [1992] studied eight models.

III. PROBLEM STATEMENT

In the face of rising energy costs and environmental concerns, conventional HVAC systems fall short in terms of sustainability and affordability. This research investigates the potential of Smart Earth Soil to Air Heat Exchangers (ESAHEs) as a viable alternative for efficient and sustainable thermal management in buildings.

IV. OBJECTIVE

The main objectives of the thesis are as follows 1. To perform an extensive literature review to identify the research and development status of this technique and current guidelines for designing earth-to-air heat exchanger systems. 2. To develop a transient thermal network model for finding the transient temperature profile around an earth tube in order to determine the optimal depth of the earth-to-air heat exchanger systems and the change of temperature of the soil due to prolonged usage. 3. To develop a new methodology for simulation of the earth tube system taking into account both heat transfer and condensation. 4. To apply this technology to Montreal climate

V. DESCRIPTION

Hardware: Sensors: High-accuracy temperature sensors for soil (potentially at different depths) and air (inlet and outlet). Humidity sensor for measuring air moisture content. (Optional) Soil moisture sensor for understanding soil moisture impact on heat transfer. Microcontroller/Single-board Computer: A central processing unit like Arduino or Raspberry Pi for data collection, processing, and communication. Data Storage: Local storage (SD card) or cloud storage for sensor data and potentially machine learning models. Communication Interface: For communication between sensors and the microcontroller (I2C, SPI). Actuators (Optional): Fans, dampers, or other control mechanisms to adjust airflow based on system decisions. Software: Data Acquisition Software: For collecting and logging sensor data at regular intervals. Machine Learning Framework: Libraries like TensorFlow or scikit-learn to train models predicting heat transfer efficiency. Control System Software: Algorithms translating model predictions into control actions for the SAHX system (fan speed, damper positions). (Optional) User Interface: Web based or mobile app for visualizing sensor data, model predictions, and system status. System Specifications: Sensor Specifications: Temperature sensors: Accuracy within ±0.5°C for reliable temperature readings. Humidity sensor: Accuracy within ±3(Optional) Soil moisture sensor: Accuracy suitable for identifying moisture levels impacting heat trans fer. Microcontroller/Single-board Computer Specifications: Processing power and memory sufficient for data collection, communication, and potentially basic control functionalities. Communication ports for connecting with various sensors and actuators. Data Storage Specifications: Storage capacity sufficient for historical sensor data and potentially trained machine learning models. Communication Interface Specifications: Protocols compatible with chosen sensors and microcontroller (I2C, SPI). Actuator Specifications (if applicable): Actuator type and power requirements based on chosen control mechanisms (fan speed, dampers). Software Specifications: Software compatibility with chosen hardware and operating systems. Security considerations for data storage and communication.

VI. WORKING DIAGRAMS

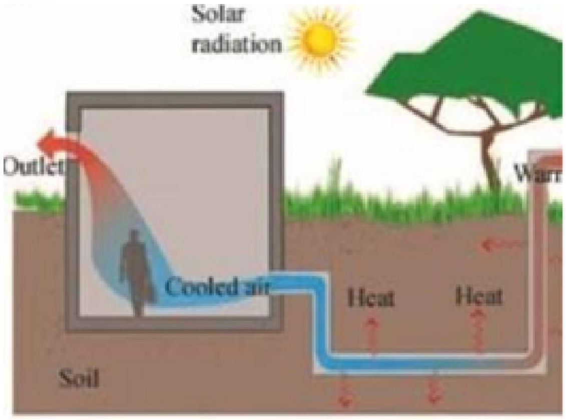

Fig no. VI.1: Flow Diagram

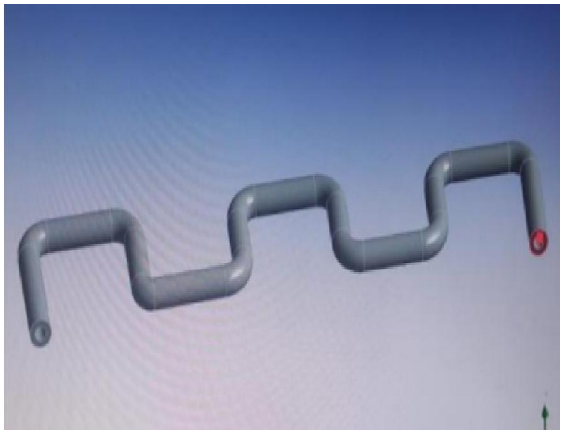

Fig no. VI.2: Selection-Outlet Of The Pipe

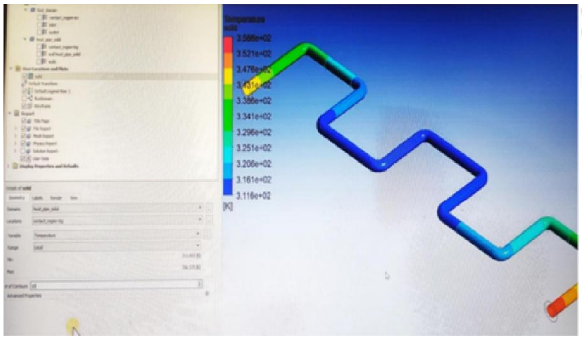

Fig no. VI.3: Temperature Variation in the tube

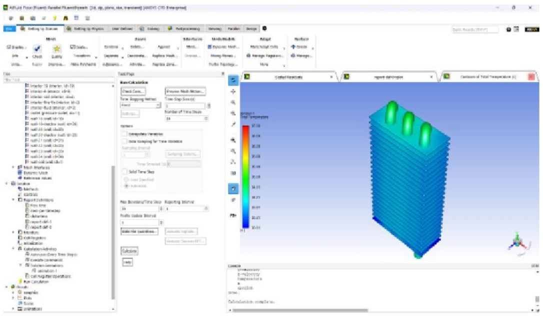

Fig no. VI.4: Fluent Analysis

VII. CONCLUSION

In conclusion, the analysis of an earth soil to air heat exchanger system reveals its potential as a sustainable and energy-efficient solution for heating and cooling ap plications. Through a detailed examination of the system components, functions, and mathematical modelling, several key conclusions can be drawn: Environmental Sustainability: Earth soil to air heat exchangers leverage the stable temperature of the ground, providing a sustainable alternative to traditional heating and cooling systems. By reducing reliance on conventional energy sources, these systems con tribute to environmental conservation. Energy Efficiency: The system’s ability to extract or reject heat from or to the ground results in improved energy efficiency. By tapping into the earth’s relatively constant temperature, less energy is needed for space heating or cooling, making the technology environmentally friendly and cost-effective in the long run. Mathematical Modelling: Mathematical models play a crucial role in understanding and predicting the performance of earth soil to air heat exchangers. These models help engineers and designers optimize the system parameters, ensuring efficient heat exchange and meeting specific project requirements. Heat Exchanger Coil Functionality: The heat exchanger coil, buried in the ground, serves as a conduit for a heat transfer fluid, facilitating the exchange of thermal energy between the soil and the air. Its 25efficient design and integration with the air handling system enable the system to achieve effective heating or cooling for buildings. 8.1 Future Scope Defining the Scope of Earth Soil to Air Heat Exchanger (ESAHE) Project The scope of your ESAHE project will depend on various factors, including our goals, resources, and specific area of interest. Here are some points to consider when defining your scope: Project Focus: Technical analysis: Focus on analysing specific aspects of ESAHE performance, such as thermal efficiency, heat transfer rates, or design optimization. Economic feasibility: Evaluate the cost-effectiveness of ESAHEs, considering initial investment, energy savings, and maintenance costs. Environmental impact: Assess the environmental footprint of ESAHEs, including greenhouse gas emissions, soil disturbance, and potential pollution risks. Prototype development and testing: Design, build, and test a small-scale ESAHE system to validate theoretical models and optimize performance. Policy and market analysis: Explore the potential role of ESAHEs in energy policy and their adoption within specific markets (residential, commercial, etc.). Project Depth: Deep dive: Narrow our focus to a specific aspect of ESAHEs and conduct a thorough analysis with de tailed research and simulations. Broaden your horizons: Encompass multiple aspects of ESAHEs, providing a general overview of their potential and challenges. Com putative analysis: Compare ESAHEs with other climate control technologies like traditional HVAC systems or geothermal heat pumps. Target Audience: Academic research: Focus on theoretical analysis, data-driven conclusions, and contributions to existing knowledge. Commercial application: Emphasize practical considerations, cost-benefit analysis, and potential market impact. Policymakers and government agencies: Highlight environmental benefits, energy security implications, 26and pol icy recommendations for ESAHE adoption. Resource Constraints: Budget: Consider the costs of equipment, materials, software, and research time when defining your project scope.

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