IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

FEASIBILITY ANALYSIS OF WELL WATER AIR TUNNEL SYSTEM - A GEOTHERMAL EXPERIMENT

Ar. Febin De Lysis,
College of Engineering, Thiruvananthapuram

***Abstract*— Seasonal variations in climatic parameters are common in warm and humid regions, implying a high potential for geothermal effects for heating/cooling applications. However, due to a lack of information about the underground temperature profiles of the surface and shallow zones, such applications are extremely limited in these regions. As a result, the objectives of this study are as follows: i. Identify the well water temperature profile in the study area; (ii) conduct a feasibility study of the well water air tunnel system (WATS) in the study area; and (iii) if the system is feasible, identify possible design solutions. Determine why the system is not feasible.**

***Keywords* -- Geothermal cooling, Well water cooling, Environmental sustainability, EATHE, Subsoil Temperature, Geothermal Energy, HVAC Systems**

INTRODUCTION

The heating of indoor space, ventilation, and air-conditioning (HVAC) systems account for around 40% of the building energy consumption, which is increasing as a result of the construction industry's rapid development. In the topic of energy conservation, building energy conservation has grown in importance. Another crucial component of a green construction is making maximum use of renewable energy sources. Geothermal energy is one of the many renewable energy sources that can be used for thermal purposes like room heating and cooling. Passive ideas are valued for reducing energy consumption in heating and cooling buildings and achieving indoor thermal comfort utilising renewable energy sources.

Geothermal Energy

Geothermal technology uses the heat of the Earth to generate electricity. In contrast to the summer and winter extremes of the ambient air above ground, the Earth maintains a near-constant temperature just a few feet below the surface. Further below the surface, the temperature rises at a rate of about 1°F for every 70 feet of depth. Higher temperatures and pockets of superheated water and steam can be found much closer to the surface in some areas due to tectonic and volcanic activity [14].

Three major types of technologies use the Earth as a heat source:

• Geothermal heat pumps
• Direct geothermal systems
• Deep and enhanced geothermal systems

Geothermal energy is a renewable source of energy. Ground source heat pumps and direct use geothermal technologies are used for heating and cooling, whereas deep and enhanced geothermal technologies generate electricity by tapping into a much deeper, higher temperature geothermal resource [14].

Earth Air Tunnel Heat Exchangers (EATHE) are frequently utilised in buildings in many different locations as one of the energy-saving methods. The basic idea behind EATHE is to employ mechanical ventilation or induced ventilation to bring in fresh outdoor air and then cool or heat it using geothermal energy. The idea makes advantage of the thermal energy stored in the subsoil to create indoor thermal comforts in both the summer and the winter. In the summer, the soil is colder than the ambient air temperature. Operating costs can be greatly reduced by using the superficial soil layer as a source of heat and cold. The air may be heated and cooled simultaneously even when the seasonal weather outside changes because of the relatively constant soil temperature inside the tunnel. At a depth of 4 m or more, the temperature of the subsoil becomes nearly constant. The constant temperature continues to be higher than the seasonal ambient average temperature in the winter and lower than the seasonal ambient average temperature in the summer (Yang L.H, 2019). Both when used independently and in a hybrid configuration with traditional HVAC systems, EATHE systems produced significant energy savings. Utilizing the system eventually reduced or may reduce GHG emissions and lessened the impact of energy problems.

When compared to traditional geothermal energy, which entails greater depth and a higher temperature, shallow geothermal energy is different. The benefits of shallow geothermal energy include renewability, convenience of use, wide dispersion, and constant temperatures. It is a low-temperature geothermal resource that is dispersed in soil at a depth of 3 to 50 metres on the earth's surface (Yang L.H, 2019).

A system that uses shallow geothermal energy is an earth-air heat exchanger (EAHE). It is a viable alternative for passive building energy-saving systems because it simply needs a fan to push air and does not require conventional air-conditioning compressors, refrigeration components, or chemical refrigerants. Well water tunnel and air tunnel analyses are looked at in light of the EATHE principle.

Working Principle

The concept behind an Earth Heat Exchanger (EAHE) system is to use the thermal mass of the earth as both a heat source and a heat sink. This is accomplished by running a system of subterranean pipes, referred to as a "heat exchanger," through which the air from the building is circulated (Gao,2022).

The EAHE system functions in the winter by taking heat from the inside air and transferring it to the cooler ground below the structure. This is accomplished by passing air from the building through the heat exchanger's underground pipes, where the heat is transmitted to the ground. The cooled air is then returned to the building to be reheated. This process is repeated indefinitely, providing a steady supply of warm air to the building.

During the summer, the EAHE system operates in reverse. The system cools the air inside the building by extracting heat from the earth and transferring it to the air. This is accomplished by circulating air from the building through the underground pipes of the heat exchanger in the opposite direction, where heat is transferred from the earth to the air. The cooled air is then returned to the building, ensuring a constant supply of cool air.

Study Location

Selected study area is Thiruvananthapuram, a south most district in Kerala state. The state of Kerala is a small region of territory with a 38863 sq. km. borders the Lakshadweep Sea on the west and Tamil Nadu and Karnataka States on the east. The State measures 560 kilometres from north to south, with an average width of 70 kilometres and a maximum of 125 kilometres. It lies between North latitudes 08018'N and 12048'N and East longitudes 74052'E and 77022'E. Kerala is situated in warm and humid area and receives abundant rainfall.

According to the present climatic situation, the maximum temperature in summer days can be almost 40°C and temperature in winter nights is almost 16°C. The use of active air conditioning systems in Kerala is becoming common these days which increases electrical energy by 60%. Using these air-cooling devices can release certain harmful chemicals and can lead to atmospheric depletion. Rainfall is the primary source of ground water recharge, and rainfall patterns have a significant impact on water levels in phreatic and deeper aquifers. The annual rainfall distribution in the year 2021-2022 shows that the state received an average rainfall of 3505 mm from 1 April 2021 to 31 March 2022. The rainfall varied by district, ranging from 2391 mm in Palakkad to 4756 mm in Pathanamthitta.

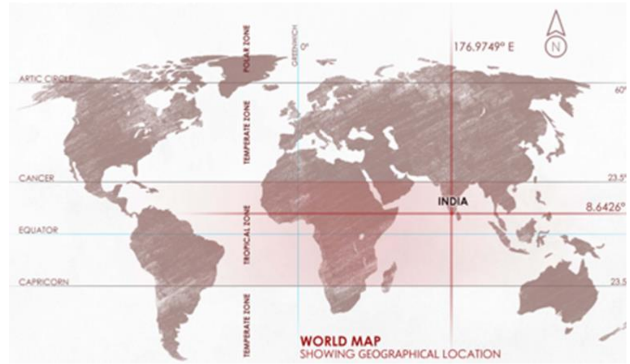

Fig.1 Geographical location

During the Southwest monsoon season, Thiruvananthapuram received the least rainfall (746 mm) and Kasaragod received the most rainfall (2399 mm), with the state average being 1729 mm. During the Northeast monsoon season, Wayanad district recorded the lowest rainfall of 570 mm and Pathanamthitta district reported receiving the most rainfall of 1695 mm, compared to the state average of 1026 mm. (Ministry of Water Resources).

AIM

To study on the feasibility of well water air tunnel system (warm and humid climate)

OBJECTIVES

To check the feasibility of this system in study location and to find the positive and negative aspects while implementing the system.

SCOPE

- Majority of people in Kerala depend on well water system
- Ground water table in Kerala is found not too deep
- Most of the regions in Kerala comes under watershed of rivers
- Taking advantage of the encircling environment and ground temperature.

METHODOLOGY

An innovative method of using geothermal energy for heating and cooling inside the living space is the earth tube heat exchanger. The main objective of this project is mention below:

1. To find an effective alternative solution for heating and cooling.
2. Moving towards a renewable source of energy.
3. Addressing technology that is more environments friendly.
4. Reducing energy consumption by passive heating and cooling system.

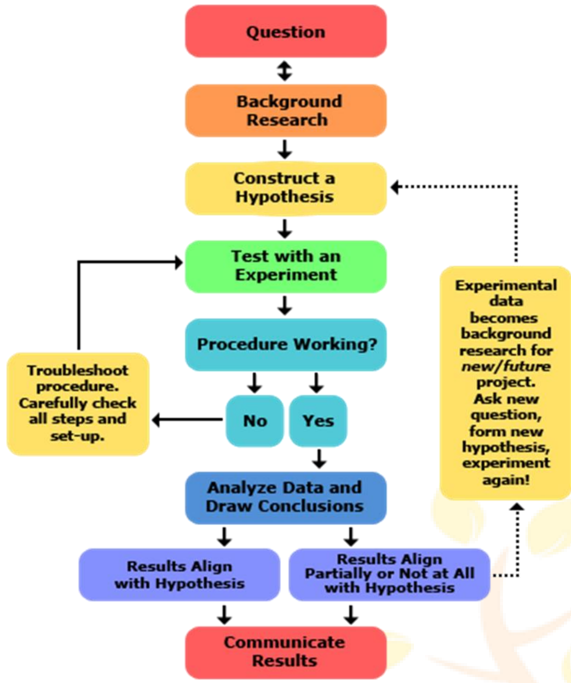

Fig.2 Methodology

INITIAL STUDY

Selection of study area

The area and the building where the study to be conducted is selected based on the terrain, water availability, soil type etc. The geographical aerial view of the study area is represented in Fig.3.

Fig.3 Aerial view of study area (Source : Google Map)

Details of Study Area and Selected Well

Location - Nedumangad (8.641014,76.978361)
Altitude - +125 msl (midland)
Sea proximity - 17 km
Soil type - Gravelly clay soil
Topography - Rocky terrain

Building Details

Floor area - 56 sqm (600sft)
Type - Concrete building with GI Roof covering
Category - 2 BHK

Well Details

Diameter - 1.4 m
Full Depth - 11.0 m
Water Depth - 4.3 m
Water Quantity - 6600 ltr

Surface air temperature and deep well water temperature

The surface air temperature and deep well water temperature were recorded for one day using digital and mercury thermometers. The graph in Fig.4 shows the variation of temperatures of surface air and well water. It was observed from the readings that, at noon time the difference showed by the surface air and well water temperature is maximum. Deep water temperature of well showing very less fluctuation in peak hours.

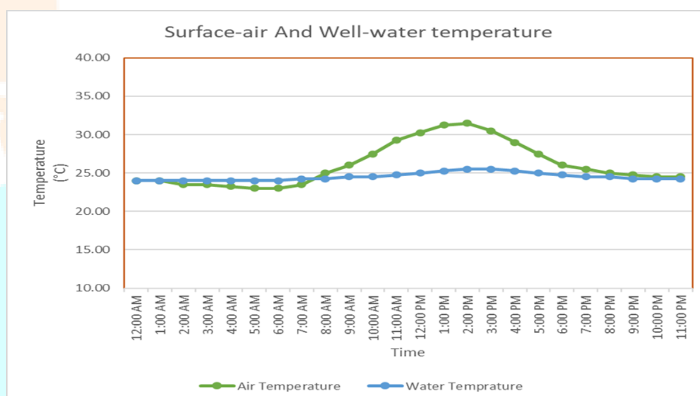

Fig.4 Variation of Surface air and deep well water temperature

Dry bulb temperature and humidity

The temperature of air as measured by a thermometer that is not insulated from radiation or moisture is known as the dry-bulb temperature (DBT). DBT is the actual thermodynamic temperature and is the temperature that is typically thought of as air temperature and is used to measure the humidity of surrounding area (Huang, Y.2013). The dry bulb temperature and humidity of the selected house are taken and noted. Fig.5 shows the variation of dry bulb temperature and humidity of rooms of the building. The dry bulb temperature and the humidity are measured using sling thermometer and digital thermometer.

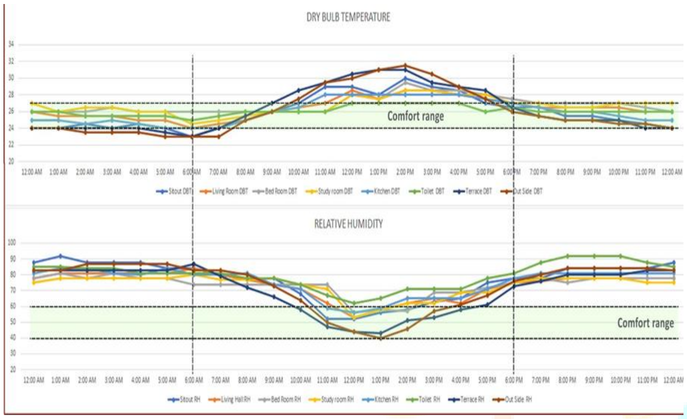

Fig. 5 Dry bulb temperature and humidity

HEAT EXCHANGER AND WORKING

<u>Design Considerations</u>

Material Selection

For this experiment, the tube material selected is iron as it is cheap and easily available than any other materials. Iron possess has good thermal conductivity, better corrosion resistance and cheaper in cost as compared to steel and PVC.

Tube Length and Diameter

Heat transfer is dependent on surface area, which varies with length and diameter. As observed in Fig.6, altering the length or diameter alters the area, which in turn alters the heat transfer, which alters the temperature at the output. The length needs to be optimised because it stops transferring heat beyond a certain point. Better thermal performance is provided by a smaller diameter, but a greater pressure drops results (Bibek Gautam,2021). Airspeed and heat transmission are reduced as tube diameter is increased. The key design problem is to maintain an adequate tube diameter to get the highest performance at the lowest cost.

So, the increased length would mean increased heat transfer rate and hence higher efficiency.

After, a certain length no significant heat transfer occurs. Hence optimize length. Increasing length also results in a pressure drop.

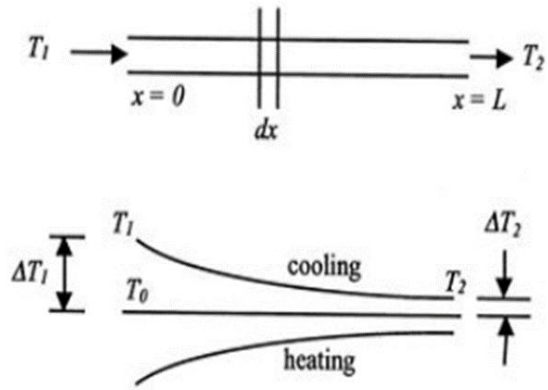

Fig.6 Temperature Distribution with the length of the tube

Tube Location

From sunny to shaded areas, earth temperatures and subsequently cooling tube performance differ dramatically. The cooling tubes themselves and the inlets for open loop systems should both be situated as close to shade as practicable.

Tube Depth

Ground temperature affected by the:
a) External climate.
b) Soil Composition.
c) Water Content.
d) Thermal Properties.

The ground temperature fluctuates in time, but the amplitude of fluctuation diminished with depth. Burying pipe/tubes as deep as possible would be ideal. Generally, 4-5m below the earth's surface dampens the oscillation significantly.

Earth Temperature

Between 20 and 100 feet (6.1-30.5 metres) below the surface of the earth, the temperature is still two to three degrees greater than the average yearly air temperature. Earth temperatures below 10-12 feet (3.1-3.7 metres) may be significantly influenced by air temperatures, and depending on the location, may change throughout the year. The temperatures on Earth roughly match those of the air near the surface.

Soil Properties

Different soil types transfer heat differently and distribute it across different areas. The conductivity and diffusivity of the soil are greatly influenced by its moisture content, which also explains why there are significant variances in how heat flows through the earth.

Potential Problems

Because the ground does not stay cool enough at a respectable depth during the summer, earth cooling tubes are likely to work poorly in hot, humid environments. Moreover, earth cooling makes it challenging to achieve dehumidification, another crucial part of cooling. Most likely, mechanical dehumidifiers will be required.

Molds and fungi that produce odours may thrive in the dark, moist environment of the cooling tubes. Additionally, moisture or seepage from the ground may build up in the tubes and promote the development of bacteria. Some of these issues might be solved by good construction and drainage.
An open-loop system's tubes are susceptible to rats and insects entering. To keep possible intruders away, you should install a strong grille and insect screen at the tube inlet.

Economics
Systems using earth cooling tubes can be highly expensive. It is unclear that an earth cooling tube installation can be justified on the basis of economics alone, given current electric power tariffs, the cost of materials, and labour.

BASIC DESIGN REQUIREMENTS

- The minimum depth of the well should be 8m. The proposed well chosen for study is about 11m
- Well storage capacity should not be less than 5000 litres.
- Distance between well and house should be within 3 to 10 m
- Heat exchanger should be made of high thermal conductive material.
- Air pump must be energy efficient and powerful.
- Inlet and outlet tubes must be made of high thermal resistive material.
- Electric energy can be produced from PV Panel.

The above assumptions and results are considered for the design of heat exchanger after the study from various literatures.

DESIGN CALCULATIONS

A list of formulas that have been used to determine the length and efficiency of earth tube heat exchangers is shown below. The input parameters with symbols, values given for the calculation with units provided are provided in Table 1

[1] Mass flow rate

$$m = (v \times \rho \times \pi \times D_i^2)/4$$

[2] Reynolds Number

$$Re = \frac{\rho v D_i}{\mu}$$

The flow in the tube is laminar for Re<2000, fully turbulent for Re>10000, and transitional in between under the most practical circumstances. However, when building a piping network, the flow with Re>4000 is considered turbulent.

[3] Amount of heat transfer

$$Q = m\,Cp\,(Tout - Tin)$$

Here, Cp provided as 462J/kgK

Coefficient of performance

$$COP = m\,Cp\,(Tout - Tin) / \text{Power input}$$

Power Input is given as 600W

Table 1 Input Parameters

Inlet Temperature	T_{in}	45	°C
Length of Tube	L	4.5	m
Thermal Conductivity of air	k_{air}	0.0266	W/mK
Thermal Conductivity of Pipe	k_{pipe}	79.5	W/mK
Thermal Capacity	C_P	462	J/kgK
Viscosity	μ	1.85×10^{-5}	N/ms
Density of Air	ρ	1.1465	kg/m^3
Velocity of air	v	10	m/s
Outer diameter of pipe	D_o	0.0723	m
Inner diameter of pipe	D_i	0.0691	m

INSTALLATION OF HEAT EXCHANGER

By considering design criteria and parameters, a heat exchanger has designed and installed. The Fig.7 shows the heat exchanger that is designed. The material consists of GI Tube of 2.5 x 15cm diameter with total length of tube as 410cm. A diameter of 5cm GI pipe is also used in the making of heat exchanger.

The below Fig. 8 gives the cross section, elevation and the plan of the heat exchanger. The total length of the heat exchanger is 60cm with width of 40cm. Loops are spaced at a distance of 6cm from each other. The outlet and the inlet valve are with a diameter of 5cm. The gauge thickness of the pipe is provided as 5mm. The surface area and weight of the heat exchanger are 1.4 sq.m and 15.6 kg respectively.

Fig.7 Designed Heat Exchanger

For the installation of designed heat exchanger, a highly insulated PVC pipes are connected at the inlet and outlet valve of the heat exchanger. The inlet and outlet tubes are exposed to outdoor temperature as to avoid heat loss and gain, tubes must have less thermal conductivity. In the inlet pipe, a mechanical blower is introduced and the outlet pipe is exposed to inner living spaces.

A mechanical blower is introduced at the inlet of pipe. The specification of the blower is given in the Table 2 and the introduced blower is shown in Fig.9.

Table 2 Specifications of blowers

Power	600 watts
Material	Plastic
Motor speed	15000 RPM
Air Volume	160 m^3/Hour
Noise Level	75dB
Pressure	300 Pa

Power	70 watts
Material	Plastic
Motor speed	18000 R
Air Volume	850 m^3/H
Noise Level	45dB
Pressure	350 Pa

Fig. 9 Mechanical Blowers

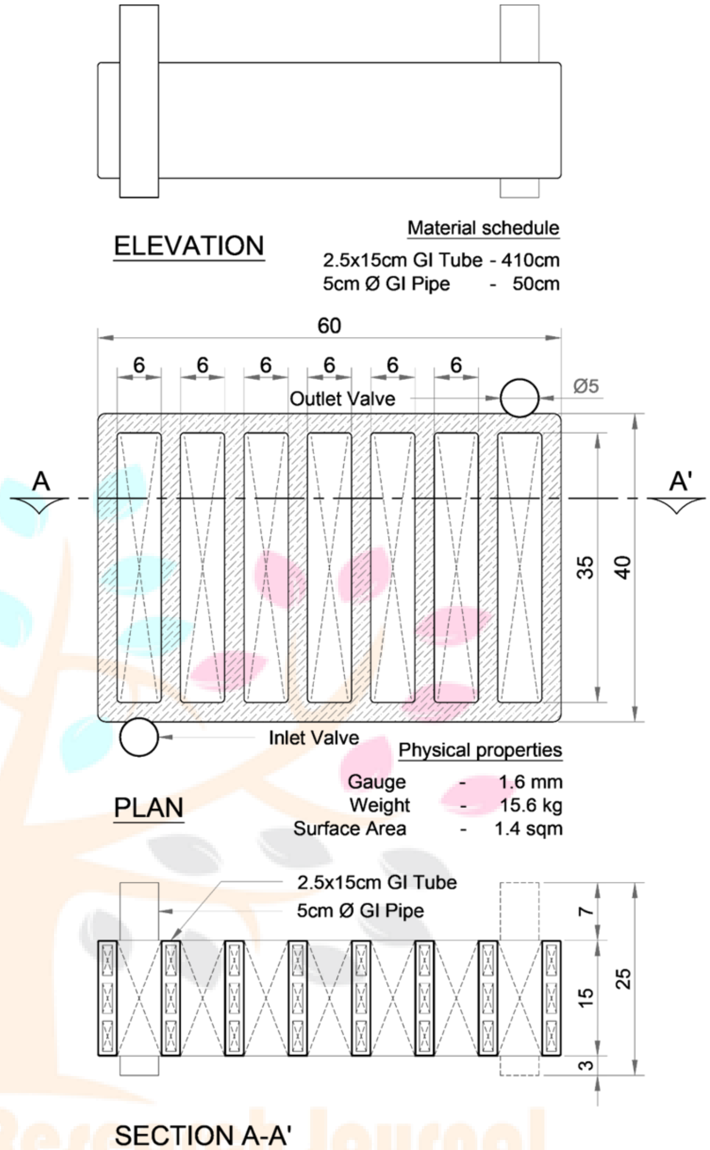

Fig. 8 Cross section, elevation, plan of heat exchanger

WORKING OF HEAT EXCHANGER

The air from the blower is provided in the inlet tube as inlet air. This air in the inlet tube goes inside the deep well. As observed earlier, the temperature of water in the deep well is below average when compared with the atmospheric temperature. The air passes through the heat exchanger which is placed in the deep well. Due to thermal conductivity of the material used for heat exchanger, the air also cools to that temperature. These air passes through the loops of the heat exchanger and then passes through the outlet pipe, which is exposed to inner living spaces. The temperature of air from the outlet pipe is found to be below the temperature of the air in the inlet. The Fig.10 shows the working of heat exchanger. The humidity is measured using sling thermometer and the temperatures are measured using digital and mercury thermometers.

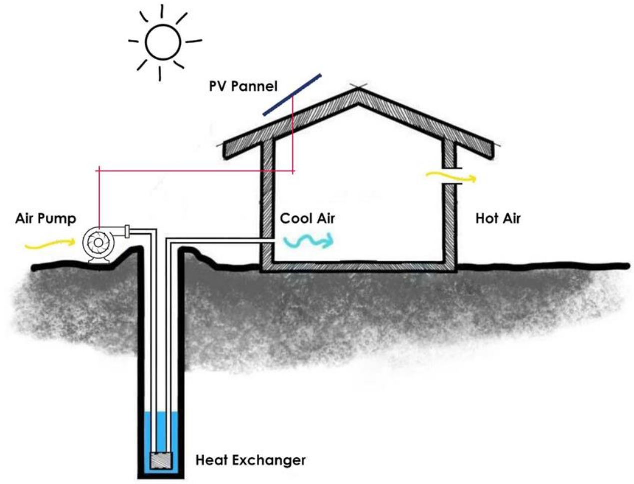

Fig.10 Working of Heat Exchanger

OBSERVATIONS AND RESULTS

- It is calculated the value of mass flow rate is 0.0429 kg/s.
- Coefficient of performance is calculated as 1.32
- Most air conditioners have a COP of 2.3 to 3.5. Higher COPs equate to higher efficiency, lower energy consumption and thus lower operating costs.
- When power input changes from 600W to 70W, COP value will be 5.94
- 20°C temperature drop is observed between the inlet and outlet pipes
- The tube material will help to increase the heat transfer rate

CONCLUSIONS

Several conclusions can be drawn from the results and observations.

- This system can effectively control daytime temperature fluctuation

When providing a well water air tunnel system, there is a temperature drop of about 20°C when compared with room temperatures.

- Super cooling is not possible (cooling below specific average temperature)

This system can maintain indoor temperature in average temperature level without any large temperature drop and can also maintain a constant cooling effect.

- Need to add other systems to control humidity related issues.

From the results obtained, it is seen that humidity is not in a controlled manner and there is no change in the results of humidity.

- Energy consumption is comparatively less
- More sustainable and eco friendly
- Heat fluctuation is directly proportional to the availability of sunlight. So solar power generation is possible here.

ACKNOWLEDGMENT

I would like to express my gratitude towards various people, who were a part of this journey of completion of my dissertation. To my guide, Dr.Manju G Nair, for her guidance, and insight throughout each phase of the research. To Dr. Bejene Kothari, Head of the Department, Department of Architecture, for providing the necessary facilities to carry out the project. To Ar. Sushanth S J, Dissertation Mentor, for his constant guidance and constructive criticisms which has been of immense help in the successful completion of this study. To my friends and seniors who have supported me on this journey, engaged in discussions and given me valuable feedback. To my parents and wife for their confidence and continued help. To all those patient, helpful people whom I have met, interviewed and had discussions with throughout the course of this study, you have all found ways to impact, aid, and facilitate my progress in your own ways.

REFERENCES

[1] Gao, X., Xiao, Y., & Gao, P. (2022) Thermal potential improvement of an earth-air heat exchanger (EAHE) by employing backfilling for deep underground emergency ventilation. Energy, Vol. 250, 123783.

[2] Singh, R., Sawhney, R. L., Lazarus, I. J., & Kishore, V. V. N. (2021) Recent advancements in earth air tunnel heat exchanger (EATHE) system for indoor thermal comfort application: A review, Renewable and Sustainable Energy Reviews, Vol. 82, pp. 2162-2185.

[3] Cao, S., Li, F., Li, X. and Yang, B. (2021) Feasibility analysis of Earth-Air Heat Exchanger (EAHE) in a sports and culture center in Tianjin, China, Case Studies in Thermal Engineering, Vol. 26, p.101054.

[4] Soares, N., Rosa, N., Monteiro, H. and Costa, J.J., (2021) Advances in standalone and hybrid earth-air heat exchanger (EAHE) systems for buildings: A review. Energy and Buildings, Vol. 253, pp.111532.

[5] Gautam, B., Bhattarai, B., Bastakoti, N., & Baral, B. (2021) Estimating the reduction in HVAC load in multipurpose hall with the use of earth air tunnel heat exchanger (at Kathmandu University). Journal of Innovations in Engineering Education, 4(2), 32-41.

[6] Yang, L. H., Huang, B. H., Hsu, C. Y., & Chen, S. L. (2019), Performance analysis of an earth–air heat exchanger integrated into an agricultural irrigation system for a greenhouse environmental temperature-control system, Energy and Buildings, 202, pp. 109381.

[7] Gan, G.(2014) Dynamic interactions between the ground heat exchanger and environments in earth–air tunnel ventilation of buildings, Energy and buildings, 85, pp.12-22.

[8] Guselnikov, M.E., Anishchenko, Y.V., Gulyaev, M.V. and Zerkalova, A.V.,(2016) June. Artesian water wells for air cooling system of premisis. In 2016 11th International Forum on Strategic Technology (IFOST) (pp. 368-372). IEEE.

[9] District, K. Government of India. Ministry of Water Resources. Delhi. Online at: http://cgwb. gov. in/District_Profile/Gujarat/Kachchh. pdf (accessed 24 April 2018)

[10] Bisoniya, T. S. (2015) Design of earth–air heat exchanger system. Geothermal Energy, Vol.3(1), pp 1-10.

[11] SNiP 41-01-2003 Heating, ventilating and conditioning.

[12] Ground Water Year Book of Kerala (2021-22)

[13] Huang, Y., Zhang, K., Yang, S., & Jin, Y. (2013). A method to measure humidity based on dry-bulb and wet-bulb temperatures. Research Journal of Applied Sciences, Engineering and Technology, Vol. 6(16), 2984-2987.

[14] Ackerman, A. S., Toon, O. B., Stevens, D. E., Heymsfield, A. J., Ramanathan, V., Welton, E. J., & Suh, H. Abt Associates (2008) BenMAP Technical Appendices. Prepared for the Office of Air Quality Planning and Standards, US Environmental Protection Agency, Research Triangle Park, NC. Available on the Internet at http://www. epa. gov/air. Atmospheric Chemistry and Physics, 8, 6469-6481.

[15] Tremblett, K., & Francis, E. (2005). One Tonne Corporate Challenge. desLibris.

[16] https://www.washingtonpost.com/climate-solutions/interactive/2021/toronto-deep-latke-water-cooling-raptors/

[17] De Paepe, M., & Janssens, A. (2003). Thermo-hydraulic design of earth-air heat exchangers. Energy and buildings, 35(4), 389-397.