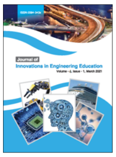

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Estimating the reduction in HVAC load in multipurpose hall with the use of earth air tunnel heat exchanger

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Abstract

Earth Air Tunnel (EAT) is a renewable form of Air Conditioning system applicable for both heating and cooling purposes with the utilization of Earth's undisturbed temperature. The Multi-purpose hall located in Dhulikhel, Kavre has a warm and humid climate. The total cooling requirement for the hall is estimated to be 763.6 kW and the corresponding ventilation requirement is 6.03 m^3/s (6.97 kg/s at 32°C/55% RH). The Earth Air Tunnel is designed for pre-conditioning the ventilated air only. Considering the optimum length of 75m, the designed earth air tunnel has 10 units parallel tube of 75 m length, 400 mm diameter, and flow velocity of 4.8 m/s. The tunnel produces the cooling effect of 132 kW when the inlet and outlet temperatures are 32°C (55% RH) and 19°C (100% RH) respectively. Cooling during humid climate the output air has higher chances to be saturated and even condenses in the tube underground. Dehumidifying the air before entering the EAT can solve this problem and thus enhance the cooling effect during the humid season to some extent. With the assumed 1000 hours per year of operation, the estimated payback time at the rate of 4% per annum (assumed subsidized case) will be 15 years. Earth Air Tunnel must be given greater care for the hot and humid zone because the cost of Earth Air Tunnel will be very high in comparison to the heat pump and also the tunnel does not guarantee to give the intended performance throughout the year which does not seem to make the project feasible for the University hall.

Abbreviations and acronyms

EAT : Earth Air Tunnel

AHU : Air Handling Unit

NTU : Number of Transfer Unit

COP : Coefficient of Performance

EUT : Earth Undisturbed Temperature

EATHE : Earth Air Tunnel Heat Exchanger

LMTD : Log Mean Temperature Difference

HVAC : Heating, Ventilation, and Air Conditioning

1. Introduction

The concept of using Earth Air Tunnel Heat Exchanger (EATHE) is not to fully handle the total HVAC load but only to assist the mechanical HVAC system to be installed. HVAC systems of a modern building need to be the most energy-efficient while not neglecting indoor air quality, system performance, and environmental issues. The main purpose of an HVAC design in a building is to provide comfort to the occupants for varying heating and cooling loads with the time of the day and time of the year. Further, any HVAC system must have effective and efficient control techniques under any load conditions [1].

The use of HVAC systems has been rapidly growing in the context of Nepal. The reason for the increasing use of HVAC systems can be because of the increasing awareness of people towards Indoor air quality and thermal comfort. Along with that, the energy demand will make a peak. Facilities managers dealing with large structures swear by the importance of free climate control. Free climate control involves maintaining the appropriate range of thermal comfort, with no use or minimum use of energy. In general, when no mechanical

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cooling is involved, it is termed to have a condition for free climate control. Going to a large auditorium attending big programs, meetings, seminars, and conferences is a big day for any individual. Every event is bigger in such halls, but that does not mean the energy bill needs to be huge too. By planning and implementing properly, it is possible to minimize the environmental impact and cost of running an auditorium [2]. It is desired to minimize the use of high-grade energy consumption and promote the use of renewable energy to save the earth from global warming due to ozone layer depletion and the cost of operation of the system.

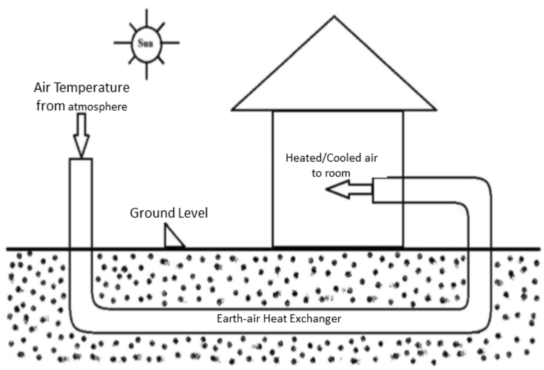

Figure 1: Schematic of Earth Air Tunnel System [3]

EATHE is one of the techniques that can be effectively implemented to heat the air in winter and vice-versa. The temperature of the earth fairly remains constant at the depth of 3-4 m throughout the year. The ambient air is drawn through the pipes of EATHE buried underground and then supplied either directly or to the AHU of the HVAC system as shown in Figure 1 [3]. Installing an energy-efficient system during building construction is considered cheaper than upgrading a system [4].

1.1. Literature

There are numerous types of HVAC systems presently being designed, developed, and operated. HVAC system depends on a large number of factors, such as the location-specific climatic condition, type of building, building purpose, building accessories, etc. Any system designed must accompany almost all of the aspects interrelated with HVAC, as intended Comfort, installation, operating cost, maintenance, environmental friendliness, etc. Achieving intended comfort with higher expenses, or achieving no comfort is not acceptable. Many sources of energy that are on waste could be utilized for achieving the condition of free climate control or changing the distribution process also contributes to the intended purpose with very little expenditure of energy. Therefore, the main challenge is to have a system utilizing the available free sources reducing the cost while not neglecting the intended purpose. Mainly the process involves controlling Temperature, Humidity, Air Quality, Air motion, and Ventilation of the indoor environment, either by cooling/heating, humidifying/dehumidifying, filtering, etc. [5].

1.1.1. Earth air tunnel heat exchanger

EATHE is one of the passive techniques for air conditioning, the main principle associated with constructing an Earth Air Tunnel (EAT) is high heat capacity and a constant temperature possessed by the underground land throughout the year [6]. The construction of an EATHE is as simple as burying several pipes underground with one end of the pipe as inlet (for fresh atmospheric) air and the next end to the outlet air for the conditioned space. The air entering the pipes exchanges heat with the pipe walls which are in contact with the surrounding underground environment, transferring heat through conduction and convection processes. The amount of heat exchanged between the air and the surrounding soil depends on parameters as the surface area of the tunnel, humidity of inlet air, the temperature of earth and air, air velocity, surface conditions of the tunnel walls, the material used for the tunnel walls, etc. An EAT is classified as an open-loop system and a closed-loop system. An open-loop system always uses the fresh air from the surroundings whereas the closed-loop system recirculates the air from the conditioned space. An open-loop system is preferred in those conditioned places where the airflow requirement by ventilation is significant [7]. Altering either the flow velocity or the diameter alters the mass flow rate of the system, so the design aspects need to optimize the system by making the least compromise in cost and comfort. EAT alone cannot be sufficient to create thermal comfort but can be integrated with a heat pump to enhance the COP of the system reducing the energy demand of the building [8]. A normal heat pump system has a COP of about 2 whereas the COP's of the system utilizing the underground air tunnel can be as high as 10 [9].

1.1.2. Internal forced convection

Pipe, duct, and conduit are interchangeably used terms for flow sections. In general, for heating and cooling applications the liquid or gas flowing through such pipes or ducts is used. Any fluids used in such applications are forced to flow with the application of a fan or pump considering that the flow section is sufficiently long to accomplish the desired heat transfer. For a fixed surface area, the circular tube gives the most heat transfer for the least pressure drop; this explains the overwhelming popularity of circular tubes in heat transfer equipment. The fluid velocity in a pipe changes from zero at the wall because of the no-slip condition to a maximum at the pipe center. In fluid flow, it is convenient to work with an average velocity v_{avg}, which remains constant in incompressible flow when the cross-sectional area of the pipe is constant. The average velocity may change in the heating and cooling applications because of a change in density with temperature, but in practice, the average velocity is taken to be constant.

Fluids at low velocities are streamlined and thus laminar, but as the velocity increases the flow turns to be turbulent beyond a critical value. Almost all of the pipe flows with low viscous fluids are turbulent. For flow in a circular tube, the Reynolds number is defined as in Equation 1.

$$R_e = \frac{\rho V_{avg} D}{\mu} \tag{1}$$

Where,

V_{avg} : Average fluid velocity

D : Diameter of the tube

ρ : Density of the fluid

μ : Dynamic viscosity of the fluid

Under the most practical condition, the flow in the tube is laminar for Re<2300, fully turbulent for Re>10000, and transitional in between but when designing a piping network, the flow with Re>4000 is considered turbulent.

From Newton's law of cooling, the rate of heat transfer to or from a fluid flowing in a tube can be expressed as in Equation 2.

$$\dot{Q} = hA_s \Delta T_{avg} = hA_s (T_s - T_m)_{avg} \tag{2}$$

Where,

h : Average heat transfer coefficient

A_s : Heat transfer surface area

ΔT_{avg} : Appropriate temperature difference between the fluid and the surface

T_s : Constant surface temperature

T_m : Mean surface temperature

ΔT_{avg} can be expressed approximately by the arithmetic mean temperature difference, but the fluid temperature does not vary linearly along the tube so we need a better way to evaluate the ΔT_{avg}. So, differentiating and integrating the relation shown in Equation 2 of heat transfer for the whole length of the tube (at inlet $T_m = T_i$ and outlet $T_m = T_m$) and rearranged equation is shown in Equation 3.

$$T_e = T_s - (T_s - T_i)\, exp\left(-\frac{hA_s}{\dot{m}C_p}\right) \tag{3}$$

The temperature difference between the fluid and the surface decays exponentially, and the rate of decay depends on the magnitude of exponents $\frac{hA_s}{mC_p}$. This dimensionless parameter is called the number of transfer units, NTU and it measures the effectiveness of the heat transfer system. Substituting and solving the relations for heat transfer and temperature gives Equation 4.

$$\dot{Q} = hA_s \frac{\Delta T_e - \Delta T_i}{ln\left(\frac{\Delta T_e}{\Delta T_i}\right)} = hA_s \Delta T_{lm} \tag{4}$$

As mentioned earlier, that the flow in a smooth tube is usually fully turbulent for Re>10000, and the turbulent flow is commonly utilized in practice because of the higher coefficient associated with it. Most of the turbulent flow relations are based on experimental studies because of the difficulty in dealing with turbulent flow theoretically. So, the Dittus-Boelter equation as shown in Equation 5 for the Nusselt number is preferred and widely used in the case with turbulent flow.

$$N_u = 0.023\, Re^{0.8}\, Pr^n \tag{5}$$

Where,

n : 0.4 for heating and 0.3 for cooling of the fluid flowing through the tube

1.1.3. Design parameters

i **Cooling load estimation**

Cooling (Heating) load is the heat that needs to be discarded (added to) from the conditioned space. The main purpose of the load estimation is to determine the capacity of the HVAC equipment required to maintain inside design conditions during the period of extreme outside conditions. The cooling load estimation generally deals with two kinds of heat gains as Sensible Heat and Latent heat [10, 11]. The sensible and latent heat is gained from any of the equipment, occupants, and processes in the space.

ii **Tube depth**

The depth of the tube is regulated by the temperature distribution below the ground. Temperature below the surface of the ground is defined by different factors as external climatic condition, soil composition, and moisture content. Rocks rich in quartz have high thermal conductivity as compared to rocks that are rich in clay or organic material. The ground temperature fluctuates higher near the surface and the fluctuation in temperature decreases with the increase in depth. Therefore, the ground temperature is very sensitive to the depth of 1m, and the fluctuation decreases with an increase in depth and remains constant after 3-4 m below the surface. The constant temperature is equal to the average annual ambient temperature. [9, 12].

iii **Tube length and diameter**

Heat transfer depends on the surface area; the surface area is a function of length and diameter. As seen from Figure 2, changing either the length or diameter changes the area, and ultimately the heat transfer changing the outlet temperature. After a certain increase in length no significant heat transfer occurs, hence the length needs to be optimized. A smaller diameter gives better thermal performance but results in a larger pressure drop. Increasing the tube diameter results in a reduction in airspeed and heat transfer. So, keeping an appropriate tube diameter to find the best performance at the lowest cost is the main design challenge [13].

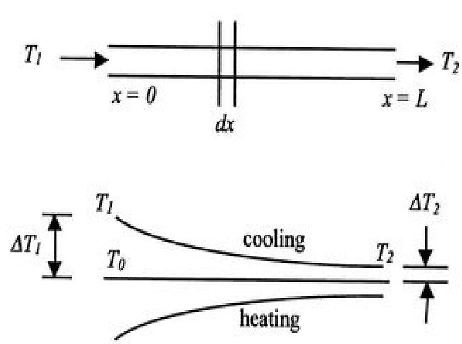

Figure 2: Temperature Distribution with the length of the tube [13]

iv **Air velocity**

During cooling increasing velocity of air results in the higher temperature of outlet air. Air velocity in a system for a required flow rate can be changed by changing the tube diameter or changing the number of parallel tubes.

v **Tube material**

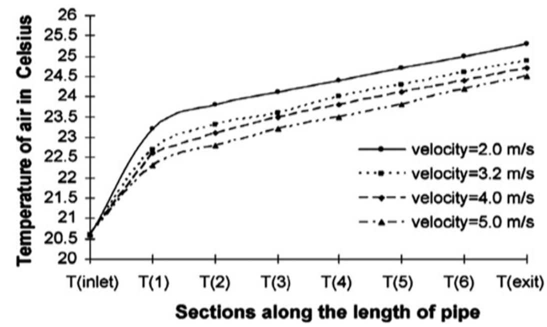

Figure 3: Outlet Temperature for different velocity with PVC pipe [13]

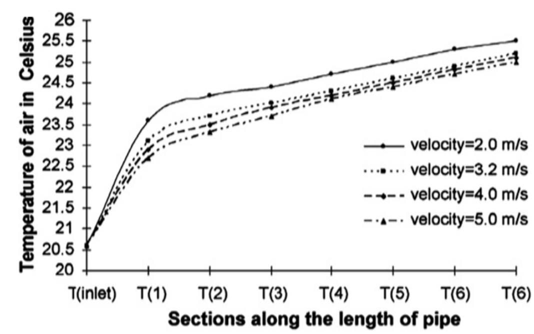

Figure 4: Outlet Temperature for different velocity with Steel pipe [13]

From the graphs in Figure 3 and 4, the tube material has a little influence on performance selection can be determined by other factors like ease of installation and maintenance. The main considerations in selecting tube material are cost, strength, corrosion, resistance, durability, etc.

vi **Tube arrangement**

Based upon the flow requirement, the diameter of the tube and velocity of the air tube arrangement can be made in either a One-tube system or a Parallel tube system. One tube system may not be appropriate to meet the air flow requirements of a building, resulting in the tube diameter is too large. So, in parallel tubes, the given flow rate can be divided reducing the size of the tube.

1.1.4. Sizing of EATHE

EET is just a component of a whole building system; there is no such freedom of choice in determining the size and layout of heat exchangers due to limited space and economic constraints. Design for an EATHE is carried out with the selection of arbitrary size diameter of the tube and with the given required mass flow rate the number of parallel tubes is calculated. The main challenge of designing an EATHE is to select an optimum combination of size and number of tubes [14, 15].

The mass flow rate of air through a tube ($\dot{m}$) for a tube diameter (D), air density (ρ), airflow velocity (v) and the number of parallel tubes (n) is shown in Equation 6.

$$\dot{m} = \frac{\frac{\pi}{4} D^2 \rho v}{n} \tag{6}$$

To simplify the design process, the following assumptions are made [15]:

- The calculations for Earth Air Tunnel are done to pre-condition the ventilated air only.
- Earth ground temperature (EUT) is constant along the length of the tube.
- The surface temperature of the ground is taken as ambient air temperature, which is equal to inlet air temperature.
- The thermal resistance of the pipe is negligible.
- The temperature on the surface of the tube is taken as uniform in the axial direction and which is equal to the earth's undisturbed temperature.
- Uniform cross-section of the tube with smooth surface at inner side.
- Thermo-physical properties (density, viscosity, thermal conductivity, and specific heat capacity, etc.) of air and soil are constant.

Heat is absorbed or released in between the air and the underground soil. Heat transfers between air and tube wall by convection and tube wall and soil by conduction. Assumed that, the contact of the tube wall with the Earth is perfect and the conductivity of the soil is very high compared to surface resistance, the wall temperature inside of the tube remains constant. Out of the methods log mean temperature difference (LMTD), the number of transfer units (NTU), and overall heat transfer coefficient NTU method is adopted because of its simplicity.

As discussed in the earlier Section 1.1.2, total heat transfer to the buried tube is given as in Equation 7.

$$Q = \dot{m} C_{p,\alpha} (T_{out} - T_{in}) \tag{7}$$

Where,

$\dot{m}$: Mass flow rate of air (kg/s)

$C_{p,\alpha}$: Specific heat of the air (J/kg-K)

T_{out} : Outlet air temperature of EATHE (°C)

T_{in} : Inlet air temperature to EATHE (°C)

Also due to convection between the tube wall and the air, the heat transfer is given by Equation 8.

$$Q = h \times A \times \Delta T_{lm} \tag{8}$$

Where,

h : Convective heat transfer coefficient (W/m^2-K)

A : Surface area of the heat exchanger (m^2)

ΔT_{lm} : Logarithmic temperature difference(°C)

Convective heat transfer coefficient, h can be calculated as in Equation 9.

$$h = \frac{NuK}{D} \tag{9}$$

Where,

Nu : Nusselts number

K : Thermal conductivity of air

D : Hydraulic diameter of the cross-section

Nusselts number is calculated from Dittus Boelter Equation 5. Prandtl number is referred from the air chart and Reynolds number is calculated with the Equation 1. Once h is determined the outlet temperature of the air can be calculated by using Equation 3. NTU is hence determined as in Equation 10.

$$NTU = \frac{hA}{\dot{m} C_{p,\alpha}} \tag{10}$$

Then, the effectiveness is determined using Equation 11.

$$\in = 1 - e^{-NTU} \tag{11}$$

In Equation 10, A = 2πrl, therefore for the required effectiveness and hence NTU the optimum length can be determined as in Equation 12.

$$l = \frac{\dot{m} C_{p,\alpha} NTU}{h} \tag{12}$$

Increasing the NTU increases the effectiveness of the system which can be seen in Figure 5. Also increasing effectiveness increases the length of the tube. But after NTU > 3 the relative gain becomes very small [14].

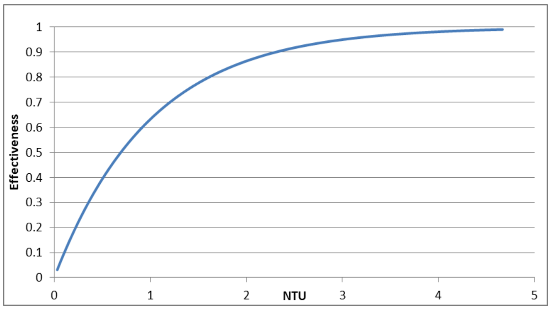

Figure 5: Effectiveness as a function of NTU

1.2. Description of System

1.2.1. The Multipurpose Hall

The hall has Seating arrangements on stage, main hall, parapet, and balcony for a total of 2150 people. The hall is spread over 1700 m^2 with an average height of 13m. The hall is planned such that it can be operated as a sports hall upon necessity. Sports with an area as large as two basketball courts can be played in the main hall. All the calculations for the hall are with the assumption that the hall operates from 9 am to 6 pm.

The cooling load for the hall is 764 kW. The ventilation requirement for the hall is 6.03 m^3/s (6.97kg/s).

2. Result and Discussion

Based on the literatures, design of EATHE is done using basic equation of heat transfer and fluid flow. The design condition varies with the change in the input parameters, area and climate being conditioned, etc. Before assuming (or calculating) a tube diameter, air velocity and tube length a pattern for the behavior of the system under different conditions is observed as below. The main purpose of observing such pattern is due to the complexity of direct method for determining the optimum parameters [15].

2.1. Calculation

For optimum design condition, considering Outdoor air parameters = 30°C and 55% RH. Therefore following data are derived.

- The specific volume of air = 0.8650 m^3/kg
- Dynamic viscosity = 1.872 $\times 10^{-5}$ kg/m-s
- Prandtl Number = 0.7282
- Thermal conductivity of air = 2.65 $\times 10^{-2}$ W/m-K
- Specific heat capacity of air = 1005 J/kg-K

Underground temperature below the depth of 3m in Dhulikhel remains constant at 18°C.

Marking different conditions varying tube diameter from 0.1m to 1m, air velocity from 1m/s to 10m/s calculation are made with the equations from Equation 7-12, to determine the number of parallel tubes, flow rate through individual tubes, heat transfers coefficients and finally the EAT outlet temperature. Also, 0.4 m diameter tube is specially focused here because it is the largest size of PVC tube available in the market in Nepal.

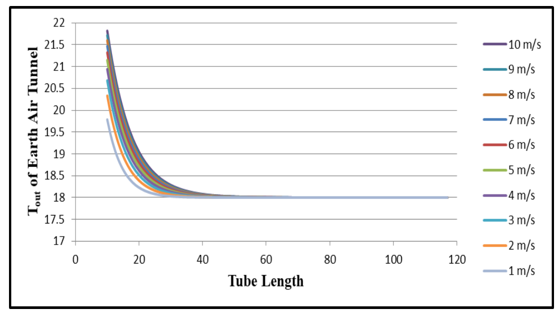

Figure 6: Outlet temperature vs. optimum tube length for tube diameter 0.1 m

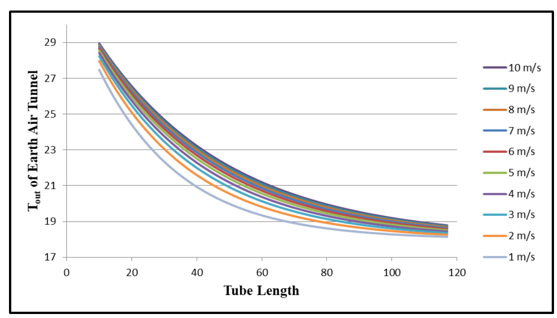

Figure 7: Outlet temperature vs. optimum tube length for tube diameter 0.4 m

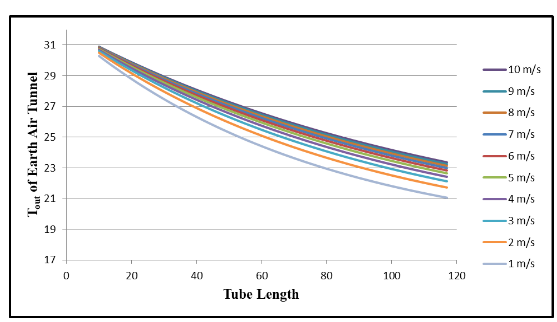

Figure 8: Outlet temperature vs. optimum tube length for tube diameter 1 m

The Figure 6, 7 and 8 show that for a constant tube diameter (0.1m, 0.4m, 1m), the increase in velocity increases the optimum tube length for the same outlet air temperature. Since the mass flow rate of a tube is directly proportional to the area of cross-section of the tube and the air velocity (from Equation 6), so when making the air velocity to the minimum the air volume that a tube can handle also be the minimum.

The graphs below are for the relation on how the outlet temperature decreases with the increase in tube length (during summer) for different diameter at constant velocity of 1m/s, 5m/s and 10m/s.

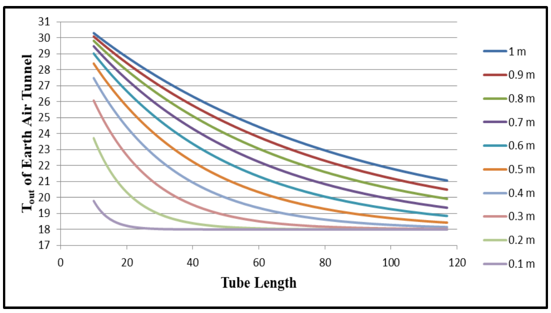

Figure 9: Outlet temperature vs. tube length for different tube diameter at 1m/s

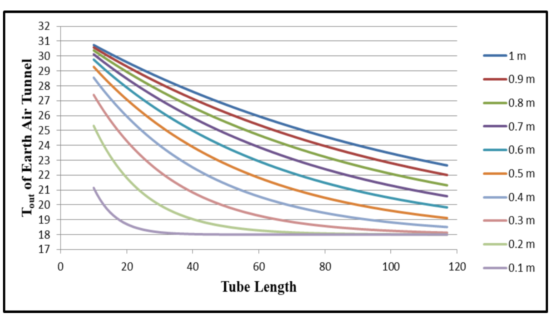

Figure 10: Outlet temperature vs. tube length for different tube diameter at 5m/s

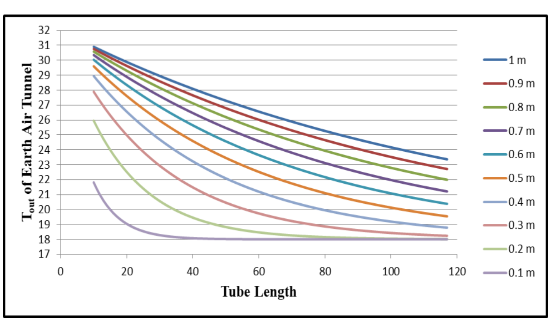

Figure 11: Outlet temperature vs. tube length for different tube diameter at 10m/s

The Figure 9, 10 and 11 show that for a constant air velocity (1 m/s, 5 m/s, 10 m/s), the increase in tube diameter increases the optimum tube length for the same outlet air temperature and vice versa. Since the mass flow rate through a tube is directly proportional to the area of cross-section of the tube and the air velocity (from Equation 6), so when making the tube diameter to the minimum the air volume that a tube can handle also be the minimum.

The main challenge with the design of EATHE is to adjust an appropriate value for tube diameter in respect to the air velocity to make the system as simpler as possible. Since from the above plots, it can be noted that decreasing either diameter or velocity decreases the optimum length of a single tube and also the volume flow rate through a tube. A decrease in volume flow rate through a single tube increases the number of parallel tubes to handle the total volume flow of the system. A large number of parallel tubes means larger length, larger excavation for installation, a larger number of connections and leakages, larger maintenances possibilities, etc. Longer tube length has problems with the tube installation and effectiveness of the system.

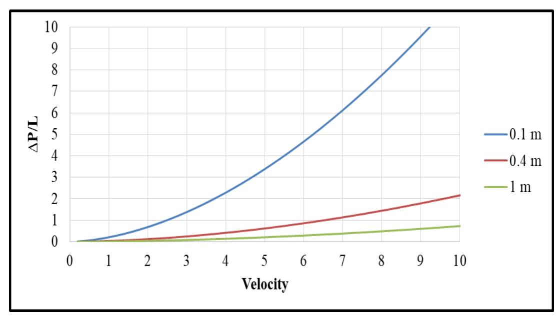

Figure 12: Pressure drop per unit length vs. air velocity for different tube diameters

Figure 12 illustrates that pressure drop per unit length increases with the increase in air velocity.

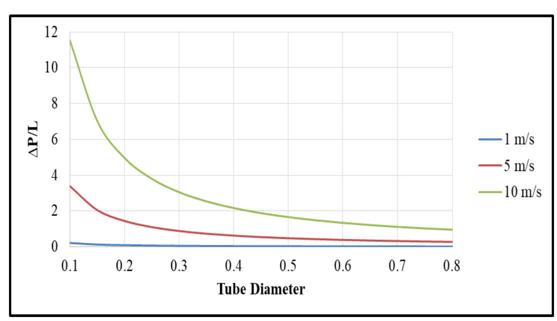

Figure 13: Pressure drop per unit length vs. tube diameter for different air velocity

Similarly, Figure 13 illustrates that the pressure drop per unit length decreases with increase in tube diameter. This suggests that while selecting the tube diameter it will not be wise to go for larger size looking for the least value of pressure gradient (Figure 13); larger diameter has longer tube length and vice versa (Figure 9, 10 and 11). Checking the feasibility for the maximum sized PVC tube available with the diameter of 0.4m.

- From Figure 12, 0.4m diameter tube has greater range of velocity and least pressure gradient for minimum optimum tube length (Figure 9, 10 and 11).

Now not keeping the velocity very less, taking 5m/s. Taking smaller velocity results in lesser mass flow rate, which in turn increases the number of parallel tubes. Taking larger velocity results in longer tube length (Figure 6, 7 and 8) and increases the pressure drop (Figure 12).

- Velocity of 5m/s has higher heat transfer than the velocity less than itself and has minimum optimum tube length value and least pressure gradient for tube diameter of 0.4m (Figure 13).

Further calculated values for the given, 0.4m diameter tube and 5m/s velocity is as follow:

- The volume flow rate through a tube =0.63 m^3/s
- Number of parallel tubes = 9.59 units
- Corrected number of parallel tubes = 10 units
- The corrected volume flow rate through a tube = 0.603 m^3/s
- Corrected air velocity = 4.8 m/s
- Reynolds Number = 118552.54
- Nusselts Number 239.62
- Convective heat transfer coefficient = 15.899 W/m^2-K
- For NTU =3, the optimum tube length = 105.18 m

Getting the value of NTU 3 is near about impossible, also the open space for the construction of EATHE has a length of < 100m. Therefore, reducing the tube length to 75m, and calculating the outlet temperature to be 19.41 °C (with an inlet temperature of 32°C). The schematics of tube arrangement is shown in Figure 14.

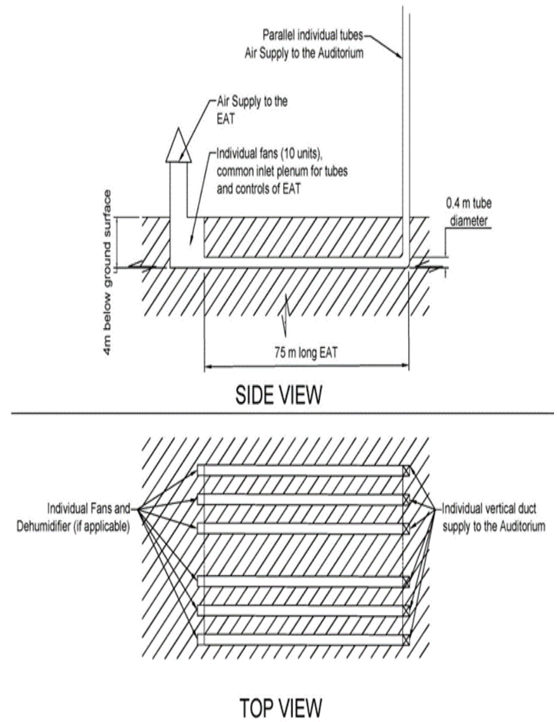

Figure 14: Schematic diagram of the complete EAT system for the multipurpose hall

2.2. Discussion

Outlet air condition from EATHE cannot be predicted just with the dry-bulb temperature. So, referring to the Psychrometric chart, when the inlet air at 32°C / 55% RH is cooled sensibly to 19.41°C at a relative humidity of 100%, the reduction in cooling load will be 132kW [6.97 kg/s × (74.6 – 55.5) kJ/kg]. This substitute for 17% of the total cooling load (763.6kW). Since the output air is saturated the water vapor gets condensed in the tube underground at the rate of 16g/s [6.97kg/s × (16.6-14.2) g/kg of moisture]. This condensation is unwanted deposition that must be removed otherwise the system gets flooded and halts. Even a small amount of moisture condensation can result in mold formation in the tube. Here the reduction in cooling load will fluctuate depending on the weather conditions. The conditions can go even worse if there is an increase in humidity also while the DBT remains constant. To produce an effective performance of EAT; the humid air before entering EAT must be dehumidified.

For the same case of inlet air, if the air is dehumidified before introducing it into EAT a greater amount of cooling can be achieved as compared to the process without dehumidification. Using a dehumidifier (32°C at 55% RH to 25% RH) to remove moisture at around 29.5 g/s, the reduction in cooling load of around 254 kW [6.97 kg/s × (74.6 – 38.07) kJ/kg] (air outlet 19.4°C/52% RH) can be achieved. This substitute for 33% of the total cooling load. The extent of moisture content and size of the dehumidifier can drastically affect the output air quality.

Table 1: Approximated calculation of costs and payback time of EAT

Parameters	Remarks
Costs per meter of EAT Construction	~ Rs. 8000
Total Length of EAT	750m
Total costs of EAT	~ Rs. 6,000,000
Cost of 92 kW heat pump	Rs. 5,021,740
Tentative yearly time of hall operation	1000 hours
Energy consumed by heat pump for 132 kW cooling	39,600 kWh
Cost of energy of Heat Pump	Rs. 3,96,000
Approximate Energy consumed by EAT (fan) (Static pressure required is not designed)	32,000 kWh
Cost of Energy by EAT	Rs. 320,000
Energy saving per year	Rs.76,000
Interest rate for payback time (Under Subsidiary Condition)	4% p.a.
Payback Time	**19 years**

3. Conclusion

EAT can be significantly used for passive heating and cooling operations depending upon the weather conditions. For designing EATHE through the sequence of calculations the diameter of the tube, the velocity of flow, and length of the tube are calculated and optimized at 0.4m, 4.8m/s, and 75m respectively. For some assumed cases reduction in cooling load by 33% and 17% with and without dehumidifier respectively is observed. Observing the percentage of load reduction, and referring the calculation from Table 1, estimating total initial cost (Nepalese Rupees ~6 million, see annex), operating hours of the Multipurpose Hall (1000 hrs/yr), and by making optimization in design parameters, the EATHE project for Multipurpose Hall does not seem to be feasible at the current moment. To make the project feasible, the hall must increase the total operating hours. Also, being bulkier system, initial construction, larger payback period and prolonged maintenance is equally difficult. Designing an EAT for the hot and humid zone is challenging as compared to the conventional air conditioning system unless it is a compulsion to stick with the renewable form of a solution because EAT does not guarantee to deliver the same and the best performance throughout every season.

4. Recommendation

If the Multipurpose Hall at Kathmandu University or similar wants to construct an EATHE, preformation evaluation of existing EAT at Butwal Power Company, Kathmandu can be done to refer to the design.

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