EXPERIMENTAL STUDY ON HEAT AND HUMIDITY CONTROL ANALYSIS INSIDE UNDERGROUND TUNNEL

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STUDENT'S DECLARATION

We do hereby solemnly declare that the work presented here in this project report has been carried out by us and has not been previously submitted to any University/ Organization for the award of any degree or certificate. We hereby ensure that the works that have been prevented here do not breach any existing copyright. We further undertake to indemnify the university against any loss or damage arising froma breach of the foregoing obligation.

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SUPERVISOR CERTIFICATION

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I wish their ever success in life.

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ABSTRACT

This project aims to create an efficient and effective ventilation system is crucial for maintaining a safe and comfortable environment in underground road networks. This abstract presents a comprehensive overview of an innovative underground road ventilation system designed to address the challenges posed by subterranean traffic. The system combines advanced engineering techniques, pollutant removal, and thermal comfort within the underground road infrastructure. The abstract highlights the key components and functionalities of the ventilation system, including air intake and exhaust mechanisms, ductwork distribution, monitoring sensors, and automated control mechanisms. The abstract also emphasizes the importance of considering factors such as traffic flow patterns, vehicle emissions, and emergency scenarios in the design and operation of the ventilation system. Through the integration of cutting-edge technologies and data-driven approaches, this underground road ventilation system aims to enhance safety, reduce energy consumption, and improve air quality for both commuters and emergency response personnel in underground road networks.

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CHAPTER 1

1.1 INTRODUCTIOIN

The tunnel ventilation system is an important element for the operational safety of a tunnel con-tributing significantly to investment and operational costs. A lot of research on road tunnel ventilation has been worked out in the 20th century. Most of the findings are still valid. In the mean- time, many experts have been retired or passed away, and taken their knowledge with them. However, in the 20th century, the focus of tunnel ventilation was on air quality in the tunnel under traffic. Vehicle pollutant emissions were a serious problem. Since the late 1990ies, air quality in and around road tunnels is rarely an issue, with some exceptions, since vehicle emissions have significantly decreased in developed countries with strict emission standards. Today, most road tunnel ventilation systems are never in operation. The focus of tunnel ventilation design and operation has shifted towards smoke control in the rare event of a fire in the tunnel. Unfortunately, in some catastrophic fire incidents, the tunnel ventilation significantly contributed to the disasters by fanning the fire and increasing the spread of smoke. In the present Road Tunnel Ventilation Compendium, comprehension of basic aspects of tunnel ventilation, in the context of general safety of road tunnels, should be advanced. Tunnel ventilation fundamentals and simple, clearly understandable und practically oriented specifications for concept, design, realization and operation of road tunnel ventilation systems shall be described. This Compendium does not comprise aerodynamic calculations; since they can be looked up in corresponding technical literature (see bibliography). Instead, open questions, common errors and ambiguities in tunnel safety and ventilation issues shall be cleared, and design hints are given, focusing on best practice when safe and reliable functionality matters.

1.2 Objective

The specific objectives of the analysis may include:

- To measure and study the inside temperature of tunnel using axial and cross airflow.
- To compare the change in temperature and relative humidity with force airflow.

1.3 Underground Road Ventilation

Underground Road ventilation system serve to limit the concentration of air pollutant during normal road operation and to transport smoke gases out of the underground road during self and assisted rescue in case of fire Road tunnel ventilation Underground Road are enclosed roadways with vehicle access restricted to portals. The specific definition of how long a roadway needs to be enclosed to constitute a tunnel varies from source to source

1.3.1 Air Quality Improvement

The primary goal of a ventilation system is to ensure the removal of harmful pollutants and contaminants, such as carbon monoxide, nitrogen dioxide, particulate matter, and other toxic gases that can accumulate in underground tunnels due to vehicle emissions.

1.3.2 Smoke Extraction in Case of Fire

In the event of a fire or smoke incident within the tunnel, the ventilation system should be capable of extracting smoke efficiently, minimizing the risk to human life and aiding emergency response teams in their efforts to control the situation.

1.3.3 Control of Temperature and Humidity

Underground road can experience extreme temperatures and humidity levels, which can be uncomfortable for drivers and passengers. An effective ventilation system should help regulate and maintain a comfortable temperature and humidity range within the underground road.

1.3.4 Reduction of Vehicle Exhaust

Vehicle exhaust emissions contribute significantly to air pollution in tunnels. The ventilation system should facilitate the efficient removal of vehicle exhaust gases to minimize their buildup and maintain a healthy air quality level.

1.3.5 Prevention of Visibility Impairment

Adequate ventilation helps prevent the accumulation of pollutants that can impair visibility within the tunnel. By removing pollutants, the system ensures clear visibility for drivers, enhancing safety during travel.

1.3.6 Emergency Response Support

An underground road ventilation system should be designed to support emergency response activities by providing a means to control smoke, facilitate evacuation, and assist emergency personnel in accessing the affected areas. Overall, the objective of an underground road ventilation system is to create a safe, healthy, and comfortable environment for motorists and pedestrians using the tunnels, minimizing the negative impacts of vehicle emissions and ensuring efficient emergency response capabilities.

1.4 Underground Tunnel Ventilation and their ventilation needs

Road tunnels have been used for more than two centuries around the world to allow road transport to avoid natural and human made obstacles such as rivers, mountain ranges and dense urban areas. Road tunnels provide for reduced travel times and improved connectivity of the road network, but their enclosed environment means that some form of ventilation is often required to maintain a safe environment within the tunnel

1.5 Ventilate use

Vehicles on the open road create emissions which are diluted and dispersed through natural surface air flows. Underground Road creates an enclosed space around vehicles where emissions from the vehicles can build up to unacceptable levels without an engineered ventilation system to replace natural surface air flows.

The main air quality criteria considered in Underground ventilation design are carbon monoxide (CO), nitrogen dioxide (NO2) and visibility Even though there are other vehicle pollutants to consider, these three criteria are considered to be the most important for health and safety. By managing air quality based on these criteria, other pollutants are managed to well below required levels.

1.6 Principles of tunnel ventilation

The basic principle of tunnel ventilation is the dilution of vehicle emissions by providing fresh air and then removing the exhaust air from the Underground Road. The exhaust air can be removed via a portal (a location where the tunnel carriageway opens up to the surrounding environment), via a ventilation outlet (such as a stack), or a combination of both. The amount of a given pollutant that is produced in a under road per unit time is determined by calculating the total number of vehicles in the Road multiplied by the emission rate of each Vehicle.

1.7 Types of ventilation system

1.7.1 Longitudinal ventilation

Longitudinal ventilation in its simplest form comprises of fresh air introduced within the entry portal and exhaust air expelled out of the exit portal. This is shown in Figure 3. Figure 4 represents the pollution profile along the length of the tunnel. The pollution level increases along the tunnel because this is the direction of airflow, and vehicles continue to generate emissions as they pass from one end to the other. In reality, tunnels in urban areas of Australia are normally graded downhill at the start of the tunnel and then uphill toward the exit, as they generally pass through relatively flat terrain. The relatively high engine load on the uphill section tends to result in higher exhaust emissions near the end of the tunnel. The design of a longitudinal ventilation system is dictated by the allowable pollution limit inside the tunnel. The way this is controlled is by ensuring that the volume of fresh air coming into the tunnel at the entry portal adequately dilutes the pollutants. This air volume can be induced by the vehicles, and is sometimes referred to as the 'piston effect'. For longer tunnels the air flow can be supplemented by ventilation fans in cases when. The traffic speed is inadequate to generate sufficient portal inflow to keep pollutant levels below the allowable limit.

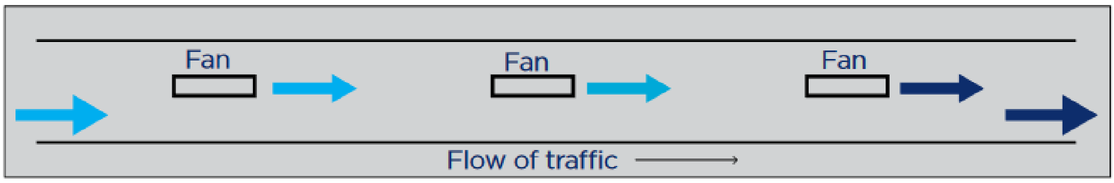

Fig: Longitudinal ventilation System

1.7.2 Transverse ventilation

Transverse ventilation works on the same principle of dilution and removal as longitudinal ventilation, but the supply of fresh air and the removal of exhaust air occurs across the Underground Road. This system requires two ducts along the length of the under road, one for the supply of fresh air and one for exhausting polluted air. These ducts can be located both at high level or low level in the tunnel, or one at low level and one at high level. Transverse ventilation has been used in the past where longitudinal ventilation could not adequately manage tunnel pollutant levels due to much higher pollutant levels in tunnels. Transverse ventilation is also effective in bi-directional Road. For these traffic conditions, the piston effect is cancelled out and the pollutant levels are more evenly distributed along the road length

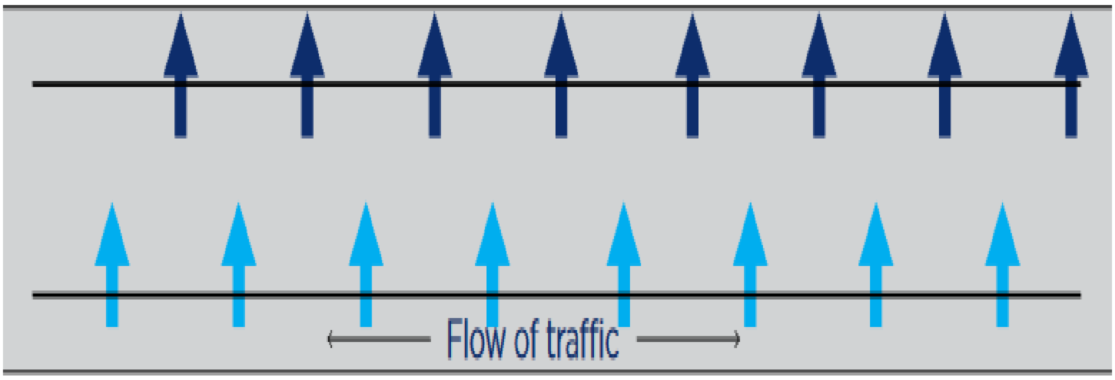

Fig: Transverse ventilation System

1.7.3 Semi-transverse ventilation

Semi-transverse ventilation is a combination of both longitudinal and transverse ventilation. Fresh air can be supplied from the portals and be continuously exhausted along the tunnel through a duct along the length of the underground road. Alternatively, fresh air can be continuously supplied along the tunnel via a duct along the length of the tunnel and exhausted out of the tunnel via the portals or a stack.

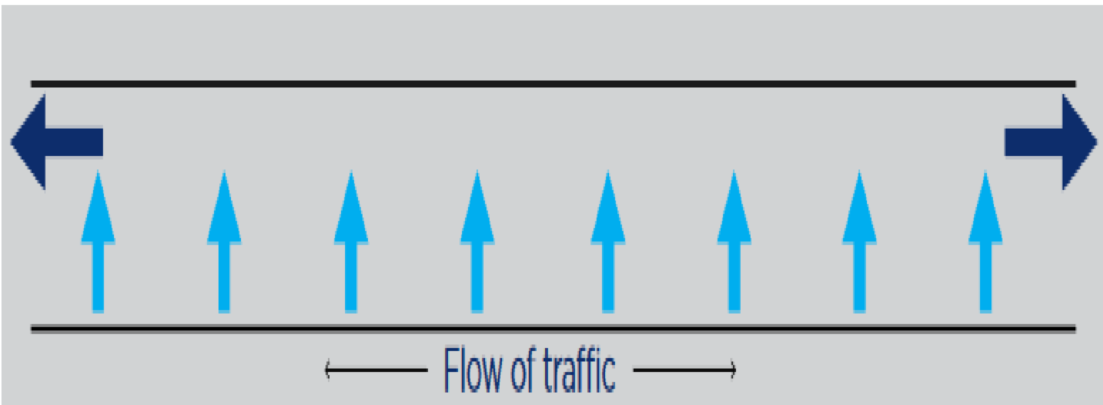

Fig: Semi-transverse ventilation

1.8 Structure for an underground ventilation road system

1.8.1 Tunnel Layout

The overall layout of the underground tunnels should be carefully designed to facilitate the movement of vehicles and people while considering the ventilation requirements. Factors such as tunnel length, cross-sectional area, and alignment are taken into account.

1.8.2 Ventilation Shafts

Ventilation shafts are vertical or inclined shafts that connect the underground tunnels to the surface. They serve as the primary entry and exit points for fresh air and the exhaust of stale air. These shafts are strategically located to maximize airflow and maintain a healthy environment underground.

1.8.3 Fresh Air Intakes

Fresh air intake is openings or ducts that allow clean air from the outside to enter the underground tunnels. They are positioned at suitable locations near the surface, such as the top of ventilation shafts or access points, and are equipped with air filters to remove contaminants.

1.8.4 Exhaust Ducts

Exhaust ducts are responsible for removing polluted or stale air from the tunnels and expelling it to the surface. They are connected to the tunnels and usually converge at the ventilation shafts, where exhaust fans or blowers create negative pressure to facilitate air movement.

1.8.5 Ventilation Fans

Ventilation fans or blowers are installed within the ventilation shafts to create airflow by either pulling air from the tunnels (extract fans) or pushing fresh air into the tunnels (supply fans). The selection and sizing of fans depend on factors such as tunnel length, traffic volume, and ventilation requirements.

1.8.6 Airflow Control

To ensure efficient airflow, various control mechanisms are employed. These may include adjustable dampers, motorized vents located at specific points within the ventilation system. These controls help regulate the direction and volume of air entering or leaving the tunnels.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this section related to underground road ventilation system are included. These provide a sampling of problem appropriate for the application of underground road ventilation system. The reference is summarized below.

2.2 Underground Road ventilation the first history

The history of underground road ventilation dates back to the construction of the first tunnels and underground roadways. One of the earliest examples of underground road ventilation can be traced back to the early 19th century during the construction of the Thames Tunnel in London, England. The Thames Tunnel, designed by engineer Marc Isamar Brunel and his son Isambard Kingdom Brunel, was an innovative project at the time. It was the first tunnel in the world to be constructed beneath a navigable river. During its construction from 1825 to 1843, the issue of ventilation was a significant challenge. To address the ventilation problem, the Brunel's implemented a unique ventilation system for the Thames Tunnel. They used a series of large steam-powered fans located at the tunnel entrances to draw fresh air in and push out the stale air and smoke generated by the steam engines and gas lamps used within the tunnel. The fans were placed in specially designed ventilation chambers, and their operation created airflow through the tunnel, improving air quality for workers and allowing for the removal of smoke and noxious gases. The ventilation system played a crucial role in ensuring the safety and health of workers during the construction process. The success of the ventilation system in the Thames Tunnel set a precedent for future tunnel projects and highlighted the importance of proper air circulation in underground roadways. Over time, advancements in technology and engineering have led to the development of more sophisticated and efficient underground road ventilation systems, incorporating elements such as air intake shafts, exhaust fans, and air ducts to maintain optimal air quality and safety in tunnels and underground road networks.

2.3 Underground Tunnel ventilation is of importance for several reasons

2.3.1 Safety

One of the primary reasons for underground road ventilation is to ensure the safety of vehicle occupants and pedestrians. Adequate ventilation helps to maintain air quality by removing pollutants, such as exhaust emissions and particulate matter, from the underground environment. It also helps to control the accumulation of toxic gases, such as carbon monoxide (CO) and nitrogen dioxide (NO2), which can be harmful to human health. Proper ventilation reduces the risk of exposure to these hazardous substances and improves the overall safety of the underground road.

2.3.2 Fire Safety

Underground roadways are susceptible to fire incidents due to the confined space and potential fuel sources such as vehicles and flammable materials. Effective ventilation plays a critical role in managing smoke and heat in the event of a fire. It helps to control the spread of smoke, facilitating evacuation routes for occupants and enabling emergency response teams to locate and combat the fire. Ventilation systems equipped with smoke extraction mechanisms aid in maintaining visibility and reducing the risk of smoke inhalation, enhancing overall fire safety.

2.3.3 Comfort and Thermal Conditions

Underground roadways are often associated with increased levels of pollutants and odors due to vehicle emissions, fuel combustion, and other sources. Ventilation systems are designed to remove these pollutants and odors efficiently, thereby improving the air quality and creating a healthier and more pleasant environment for road users. Effective control of pollutants not only benefits the health and well-being of individuals but also minimizes the negative environmental impact of underground roadways on surrounding ecosystems.

2.3.4 Control of Pollutants

Underground roadways are often associated with increased levels of pollutants and odors due to vehicle emissions, fuel combustion, and other sources. Ventilation systems are designed to remove these pollutants and odors efficiently, thereby improving the air quality and creating a healthier and more pleasant environment for road users. Effective control of pollutants not only benefits the health and well-being of individuals but also minimizes the negative environmental impact of underground roadways on surrounding ecosystems.

2.3.5 Structural Preservation

Adequate ventilation systems help to manage humidity levels within underground roadways, preventing the accumulation of moisture and reducing the risk of corrosion and structural deterioration. By controlling moisture and preventing condensation, ventilation systems contribute to the longevity and structural integrity of the infrastructure, minimizing maintenance costs and ensuring the safe operation of the underground road.

In summary, underground road ventilation is essential for maintaining a safe, comfortable, and healthy environment for road users. It plays a critical role in ensuring air quality, fire safety, thermal comfort, pollutant control, and structural preservation. Effective ventilation systems contribute to a better overall experience for individuals utilizing underground roadways while promoting safety and sustainability.

2.4 The goals of underground road ventilation

2.4.1 Maintain Air Quality

One of the primary goals of underground road ventilation is to maintain a healthy and breathable environment for road users. Ventilation systems aim to remove pollutants, such as exhaust emissions, particulate matter, and harmful gases (e.g., carbon monoxide and nitrogen dioxide), from the underground space. By continuously exchanging and refreshing the air, ventilation systems help reduce the concentration of pollutants and ensure a safe and clean atmosphere within the tunnel or underground road.

2.4.2 Control and Manage Smoke in Case of Fire

In the event of a fire in an underground road or tunnel, the ventilation system plays a crucial role in managing smoke and heat. The goal is to control the spread of smoke and provide clear evacuation routes for occupants. Ventilation systems equipped with smoke extraction mechanisms help remove smoke and maintain visibility, allowing emergency response teams to locate and address the fire effectively. Controlling smoke ensures the safety of road users and facilitates the swift and orderly evacuation of the area.

2.4.3 Prevent Overheating

Underground roadways can experience elevated temperatures due to limited natural ventilation and heat generation from vehicles. The goal of ventilation systems is to dissipate heat and provide comfortable thermal conditions for road users. By promoting air circulation and heat transfer, ventilation helps prevent the formation of hotspots and maintains a pleasant environment within the underground space. This enhances the comfort and well-being of individuals using the road.

2.4.4 Ensure Structural Integrity and Durability

Moisture control is a vital aspect of underground road ventilation. Excessive moisture and condensation can lead to corrosion and deterioration of the infrastructure, potentially compromising its structural integrity. Proper ventilation aims to manage humidity levels, prevent condensation, and minimize moisture-related damage. By preserving the structural integrity of the underground road, ventilation systems contribute to its long-term durability, reducing maintenance costs and ensuring safe operation.

2.4.5 Energy Efficiency

Energy efficiency is an increasingly important goal in ventilation system design for underground roadways. The aim is to achieve effective air quality control and thermal comfort while minimizing energy consumption. By optimizing ventilation strategies, such as using intelligent control systems, variable speed fans, and energy recovery technologies, the goal is to reduce energy usage and associated costs, making the ventilation system more sustainable and environmentally friendly.

2.4.6 Comply with Regulations and Standards

Underground Road ventilation systems must comply with relevant regulations and standards regarding air quality, fire safety, and environmental impact.
The goal is to ensure that the ventilation design meets the required criteria for pollutant levels, smoke control, emergency response, and other safety considerations. Compliance with regulations is essential to guarantee the well-being and safety of road users and to meet legal obligations.

CHAPTER 3

3.0 Design Considerations

- Underground road geometry and layout.
- Traffic volume and emission characteristics.
- Meteorological conditions.
- Fire safety regulations.
- Smoke control and extraction systems.

3.1 Underground Tunnel geometry and layout

3.1.1 Cross-Sectional Shape

The shape of the tunnel cross-section influences the airflow patterns and ventilation requirements. Common cross-sectional shapes include circular, horseshoe, rectangular, and oval. The shape determines the surface area available for ventilation openings, the flow resistance, and the distribution of air within the tunnel.

3.1.2 Under Tunnel Length and Width

The length and width of the tunnel impact the overall ventilation requirements. Longer tunnels may require additional ventilation systems or alternate ventilation strategies to ensure proper air circulation. The width of the tunnel affects the spacing and size of ventilation openings along the tunnel walls or ceiling.

3.1.3 Under Tunnel Gradient

The slope or gradient of the tunnel affects the direction and speed of air movement. In uphill or downhill sections, ventilation systems need to account for potential airflow restrictions or changes in natural ventilation patterns. The gradient can influence the selection of ventilation equipment and the positioning of ventilation openings.

3.1.4 Underground Tunnel Alignment and Curvature

The alignment and curvature of the tunnel can impact the airflow patterns. Curved tunnels create turbulence and can affect the distribution of air within the tunnel. Ventilation systems need to consider these factors and ensure sufficient airflow throughout all sections of the tunnel.

3.1.5 Ventilation Openings

The location, size, and distribution of ventilation openings, such as air supply inlets and exhaust outlets, depend on the tunnel geometry and layout. These openings facilitate air exchange and control airflow direction. They are strategically positioned to optimize air circulation, pollutant removal, and smoke control.

3.1.6 Emergency Exits

The layout and positioning of emergency exits and escape routes are important considerations in tunnel ventilation design. These exits need to be adequately ventilated to ensure safe evacuation in case of emergencies. Ventilation systems should ensure that smoke is effectively cleared from emergency exit routes to maintain visibility and facilitate safe evacuation. Designing an effective ventilation system requires a comprehensive understanding of tunnel geometry and layout. By considering these factors, engineers can develop ventilation strategies that ensure proper airflow, pollutant control, and fire safety throughout the underground road network.

3.2 Traffic volume and emission characteristics

The traffic volume and characteristics of an underground road ventilation system depend on various factors, including the size and purpose of the underground road, the type of vehicles using the road, and the local regulations and design considerations. Here are some key points regarding traffic volume and characteristics in relation to underground road ventilation systems

3.2.1 Traffic Volume

The traffic volume refers to the number of vehicles using the underground road within a specific period. The volume can vary significantly based on factors such as location, time of day, day of the week, and specific events or circumstances. High-traffic areas such as urban centers or major transportation hubs might experience heavy traffic volumes throughout the day.

3.2.2 Vehicle Types

The characteristics of the vehicles using the underground road also impact the ventilation system. Different vehicle types generate varying amounts of exhaust gases and heat. For example, tunnels accommodating predominantly passenger vehicles will have different ventilation requirements compared to tunnels designed for trucks or buses.

3.3.3 Pollutant

Vehicle emissions particularly exhaust gases such as carbon monoxide (CO), nitrogen oxides (NOx), and particulate matter (PM); need to be considered when designing the ventilation system. Ventilation systems are designed to control and remove these pollutants to maintain air quality and ensure the safety of road users and nearby residents.

3.3.4 Ventilation System Design

The ventilation system in an underground road typically consists of supply and exhaust airflows. The supply airflow brings in fresh air to dilute pollutants, while the exhaust airflow removes contaminated air from the tunnel. The design of the ventilation system considers factors like traffic volume, vehicle types, speed, and potential emergency scenarios.

3.5 Emergency

Underground road ventilation systems must be capable of handling emergency situations, such as fires or accidents, which can generate high levels of smoke and toxic gases. In these cases, the ventilation system should be able to rapidly remove smoke and provide clear evacuation routes for road users.

3.3.6 Airflow Control

The ventilation system may incorporate various control mechanisms to adjust airflow based on real-time conditions. This can include monitoring systems for pollutant levels, temperature, humidity, and visibility. Automated control systems can adjust airflow rates and direction as needed to maintain safe and comfortable conditions within the under road.

3.3.7 Safety Measures

Underground road ventilation systems are designed with safety features such as smoke detection systems, emergency communication systems, and evacuation routes. These measures are crucial for ensuring the safety of road users and facilitating efficient response in case of emergencies.

3.4 Meteorological conditions

Ventilation in underground road systems is crucial for maintaining safe and comfortable conditions for drivers and pedestrians. The meteorological conditions that impact underground road ventilation include

3.4.1 Temperature

Underground environments can be naturally cooler than the surface, but they can also become hot due to heat generated by vehicles and equipment. The temperature affects the ventilation design and the need for cooling or heating systems.

3.4.2 Humidity

The humidity level underground can vary based on the location, depth, and proximity to water sources. High humidity can contribute to discomfort, condensation, and the growth of mold or mildew, which can impact air quality.

3.4.3 Pressure Differentials

Pressure differentials between the underground road system and the surrounding environment can affect airflow. Maintaining appropriate pressure differentials is necessary to prevent air leakage or infiltration of pollutants from adjacent areas.

3.4.4 Air Quality

Underground road systems can be prone to poor air quality due to vehicle emissions, construction activities, and limited air circulation. Monitoring and controlling the concentration of pollutants such as carbon monoxide (CO), nitrogen dioxide ($NO2$)

3.5 Fire safety regulation

3.5.1 Smoke Detection and Alarm Systems

Install smoke detection and alarm systems throughout the underground road network. These systems should be interconnected and linked to a centralized control room for prompt response and evacuation coordination.

3.5.2 Emergency Lighting

Maintain adequate emergency lighting along the underground roadways to ensure visibility during power outages caused by fire incidents. Emergency lighting should be designed to withstand high temperatures and provide clear visibility for safe evacuation.

3.5.3 Emergency Exits

Clearly mark emergency exits and evacuation routes. Ensure that the routes are easily accessible, free from obstructions, and well-maintained.

3.5.4 Firefighting Equipment

Install fire extinguishers, hose reels, and other firefighting equipment at regular intervals along the underground roadways. Train personnel on how to use the equipment effectively and conduct regular inspections to ensure proper functioning.

3.5.5 Regular Maintenance and Inspections

Conduct regular maintenance and inspections of the ventilation system, smoke detectors, fire suppression systems, and other fire safety equipment. Address any issues promptly to ensure their proper functioning during an emergency.

3.6. Underground tunnel ventilation working

The working principle of an underground road ventilation system revolves around the circulation of air to ensure a safe and comfortable environment within the tunnel. The system consists of several key components and functions. Firstly, fresh air is supplied from external sources to maintain air quality and oxygen levels. This supply air is typically taken from clean sources near the tunnel entrances, and filters may be employed to remove contaminants.

Simultaneously, polluted air, vehicle emissions, and heat generated within the tunnel are extracted through exhaust systems. These exhaust systems are strategically placed at regular intervals along the tunnel and are connected to ventilation buildings or exhaust towers.

To facilitate air movement and prevent stagnant pockets, jet fans are installed at various locations in the tunnel. These jet fans create airflow patterns and can be controlled to direct air in specific directions, aiding in the dispersion of pollutants and ensuring a uniform airflow throughout the tunnel.

In case of emergencies, such as fires or hazardous releases, emergency ventilation systems are activated. These systems are designed to swiftly remove smoke, toxic gases, and heat from the tunnel, enhancing visibility and facilitating safe evacuation.

The entire ventilation system is managed by a central control system that monitors and regulates the operation of the components. It can adjust fan speeds, control airflow direction, and activate emergency ventilation systems based on real-time data from sensors. These sensors may include air quality monitors, temperature sensors, and smoke. Overall, the underground road ventilation system aims to maintain air quality within acceptable limits, control temperature and humidity, and ensure the safety and comfort of individuals within the tunnel environment. By supplying fresh air and extracting pollutants, the system mitigates the adverse effects of vehicle emissions and other sources of contamination, enhancing the overall tunnel experience for road users.

3.7 Under road ventilation Heat remove system

Determine the size and layout of the space you want to cool. Consider factors such as the depth of the underground area and the amount of heat generated.

3.7.1 Design the ventilation system

Work with a professional engineer or HVAC specialist to design a suitable underground ventilation system. Factors to consider include the airflow requirements, the type of fans or blowers needed, and the ductwork design.

3.7.2 Locate the intake and exhaust points

Identify suitable locations for the intake and exhaust points. The intake should be located in a cool area or near a source of fresh air, while the exhaust should be positioned to expel hot air away from the space.

3.7.3 Install ductwork

Lay out the ductwork system connecting the intake and exhaust points. Ensure the ducts are appropriately sized and insulated to minimize heat transfer. Use smooth, rigid ducts to reduce airflow resistance.

3.7.4 Install fans or blowers

Place fans or blowers at the intake point to draw in fresh air. Consider using fans with variable speed controls to adjust airflow as needed. The fans should be designed to handle the volume and pressure requirements of the system.

3.7.5 Install grilles and vent

Install grilles or vents in strategic locations to facilitate air circulation. These can help distribute the cooled air throughout the space and allow hot air to escape.

3.7.6 Control the system

Install controls to regulate the ventilation system. These may include temperature sensors, thermostats, and dampers to adjust airflow. Automated controls can optimize the system's performance.

3.7.7 Monitor and maintain the system

Regularly check and clean the ventilation system to ensure proper airflow. Monitor temperature and humidity levels to ensure optimal cooling efficiency. Schedule routine maintenance to keep the system in good working condition.

3.8 Advantage of Underground Road Ventilation

3.8.1 Improved air quality

Underground road ventilation helps to maintain better air quality within tunnels by removing pollutants such as vehicle emissions, dust, and fumes. It helps to reduce the concentration of harmful substances, providing a healthier environment for drivers and passengers.

3.8.2 Heat and smoke extraction

In the event of a fire or accident within the tunnel, underground road ventilation systems play a crucial role in extracting heat and smoke. They help to mitigate the spread of fire, improving the safety of tunnel users and facilitating the evacuation process.

3.8.3 Reduction of visibility issues

Underground road ventilation systems assist in maintaining clear visibility within under road by removing, exhaust gases, and other particles that can obstruct the view. This enhances safety and reduces the risk of accidents caused by limited visibility.

3.8.4 Temperature regulation

Ventilation systems can help regulate the temperature inside tunnels. By introducing fresh air and removing excess heat, they contribute to a more comfortable driving environment. Additionally, they prevent the formation of condensation, which can lead to slippery road conditions.

3.8.5 Reduction of humidity and moisture

Underground environments are prone to higher humidity levels, which can result in the formation of mold, corrosion, and other issues. Proper ventilation helps to control humidity, reducing the likelihood of such problems and extending the lifespan of tunnel infrastructure.

3.8.6 Energy efficiency

Advanced ventilation systems incorporate energy-saving technologies, such as variable speed fans and heat recovery systems. These features optimize energy consumption by adjusting ventilation rates based on real-time conditions, resulting in reduced operational costs and environmental impact.

3.8.7 Emergency response support

In emergency situations, underground road ventilation systems can aid emergency responders by providing access points for fresh air and facilitating the evacuation of occupants. These systems are often equipped with emergency smoke control features, allowing for rapid extraction of smoke in critical situations.

3.9 Disadvantage of Underground Tunnel Ventilation

3.9.1 Cost

Maintaining underground road ventilation systems can be expensive. Construction costs for ventilation shafts, fans, ductwork, and monitoring equipment can be substantial. Additionally, regular maintenance and repairs add to the overall cost.

3.9.2 Complex Design and Installation

Underground road ventilation systems require careful design and planning. They involve complex engineering and construction techniques. Installing the necessary infrastructure in existing underground road networks can be challenging, disruptive, and time-consuming.

3.9.3 Limited Effectiveness

Achieving effective air circulation throughout the entire underground road network can be difficult. Factors such as the length and layout of under road, the presence of sharp turns or steep gradients, and varying traffic conditions can affect the airflow. It is challenging to ensure consistent air quality and pollutant removal in all areas of the underground road network.

3.9.4 Energy Consumption

Operating ventilation systems requires a significant amount of energy. The fans and other equipment consume electricity continuously, resulting in increased energy demands. This not only adds to the operational costs but also has environmental implications due to increased energy consumption and carbon emissions.

3.9.5 Noise and Vibration

Ventilation fans and equipment can generate noise and vibration, which may be a nuisance to nearby residential or commercial areas. The noise generated by the fans can also be transmitted to the surface through ventilation shafts, potentially causing disturbances for the surrounding environment.

3.9.6 Maintenance Challenges

Maintaining underground road ventilation systems can be challenging due to limited accessibility. Regular inspections, cleaning, and repairs may require specialized equipment and trained personnel. Additionally, the presence of pollutants, such as vehicle exhaust fumes, can contribute to the deterioration of ventilation equipment and infrastructure, requiring frequent maintenance.

CHAPTER 4

Experimental Setup

4.1 Introduction

Ventilation is one of the most important issues in underground road transport systems. In addition, the optimal functioning of the ventilation system. In this context, it is worthwhile to mention that there were several important incidents in underground road transport systems around the world in the last few years. In these events, the main danger to passengers' life is the inhalation of smoke and toxic gases as these are released in almost completely enclosed areas.

The temperature difference between an underground road and the outside environment can vary depending on various factors such as depth, insulation, ventilation, and the climate of the region. Generally, underground roads tend to have a more stable and moderate temperature compared to the fluctuations experienced on the surface. Here are some considerations:

The deeper an underground road is, the less it is influenced by surface temperature changes. Deeper tunnels may have a relatively constant temperature, typically closer to the average temperature of the earth in that particular region.

Proper insulation can help minimize heat exchange between the underground road and the surrounding soil or rock. Insulation can reduce the temperature difference between the inside and outside.

Underground roads may have ventilation systems that regulate airflow and control temperature. These systems can help maintain a comfortable temperature inside the tunnels and remove excess heat generated by vehicles or other sources.

The climate of the region plays a significant role in determining the temperature difference. In hot climates, underground roads may have a cooler temperature compared to the outside, while in cold climates; they may be warmer than the surface.

The temperature difference and airflow in an underground road can be influenced by various factors.

4.2 Parallel Airflow System

Parallel airflow system ambition temperature to tunnel model temperature after five minutes temperature different, recorded temperature and relative humidity after on the fan and heater for five minutes, showing a c hange in temperature and relative humidity, after on for another five minutes there was a further difference in temperature, so noticed temperature and relative humidity difference of up to 30 minutes, a temperature rise of 2.5 degrees Celsius and relative humidity -1, it has decreased.

It would have been better to take the temperature and relative humidity difference every minute, we have recorded the temperature and relative humidity difference every five minutes. Here up to 30 minutes were recorded, if it could have been done more, then more temperature difference would have been seen.

4.3 Axial Airflow System

Axial airflow system ambition temperature to tunnel model temperature after five minutes temperature different, recorded temperature and relative humidity after on the fan and heater for five minutes, showing a change in temperature and relative humidity, after on for another five minutes there was a further difference in temperature, so noticed temperature and relative humidity difference of up to 30 minutes, a temperature rise of 2.4 ^{O}C and Relative Humidity -3% it has decreased from ambient temperature.

It would have been better to take the temperature and relative humidity difference every minute, we have recorded the temperature and relative humidity difference every five minutes. Here up to 30 minutes were recorded, if it could have been done more, then more temperature and relative humidity difference would have been seen.

Parallel airflow systems recorded temperature and relative humidity differences of up to 30 minutes, a temperature rise of 2.5 degrees Celsius, and relative humidity -1, it has decreased. Other way Axial airflow systems recorded temperature and relative humidity differences of up to 30 minutes, a temperature rise of 2.4^{O}C, and relative humidity -3% it has decreased. From ambient temperature to axial airflow systems. The Parallel (Shown in Fig: 4.4.2 & Table: 5.1.1) showed higher temperature and relative humidity was higher, more than the Axial airflow system (Fig: 4.5.2 & Table: 5.4.1). On the other hand, the parallel showed lower temperature and relative humidity was lower, the reason for the Axial being lower than the Parallel higher Axially airflow is expelled in a Axial system, so in a Axial system, the temperature is lower, in Parallel systems, the temperature is higher and the relative humidity is also higher. The reason is that the length of the tunnel has increased due to the internal air being taken out through the Parallel system, so the Parallel temperature and humidity are higher.

4.4 Parallel Airflow System in Lab setup- 01

Figure: 4.4.1 Tunnel model with Fan in Lab

4.4.2 Parallel Airflow System Setup- 01

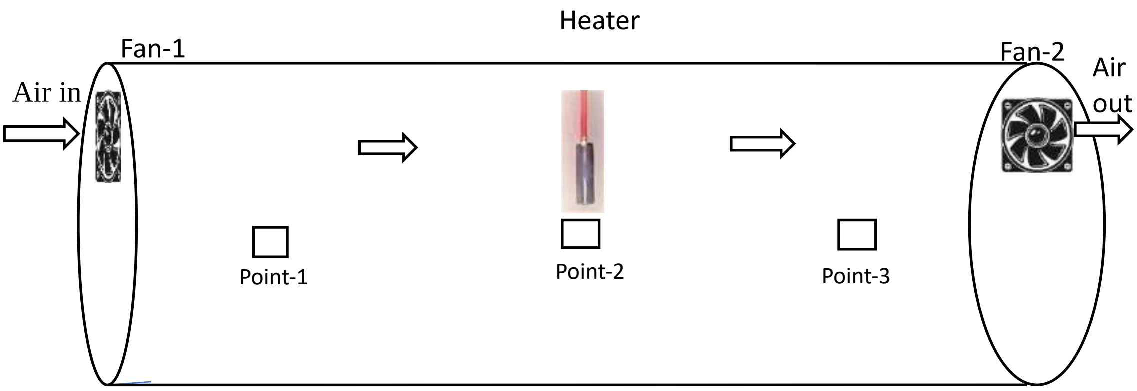

Figure: 4.4.2 Tunnel model with Fan & Heater

4.4.3 Parallel Airflow system- Setup- 01

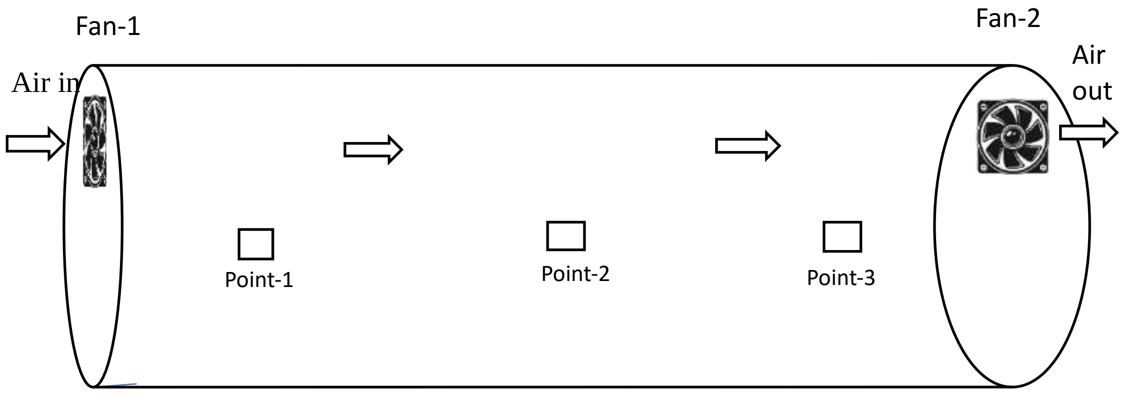

Figure: 4.4.3 Tunnel model with Fan

4.4.4 Natural Airflow system Setup -01

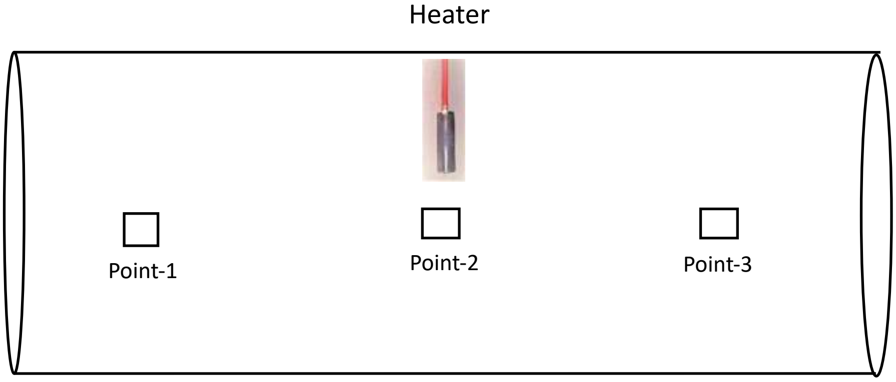

Figure: 4.4.4 Tunnel model with Heater

4.5 Axial Air Flow system setup- 02

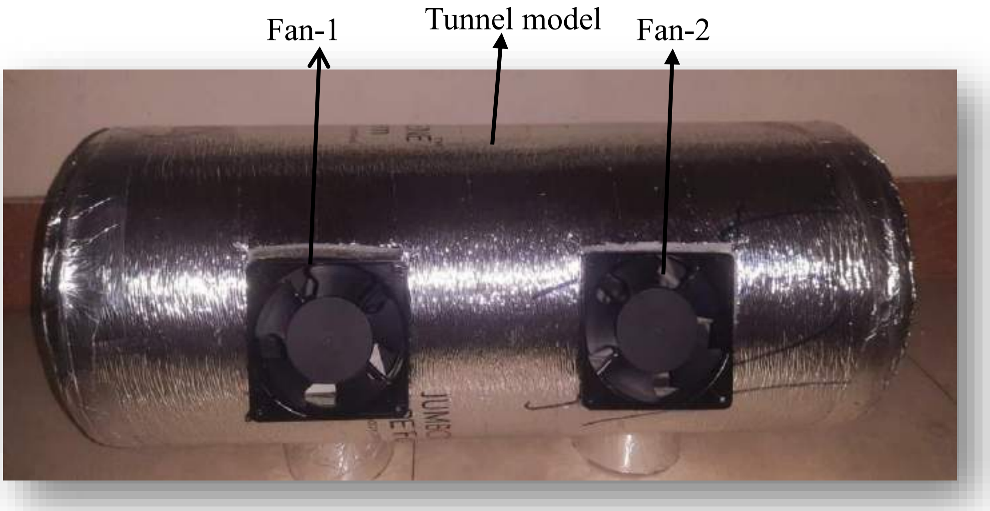

Figure: 4.5.1 Tunnel model with Fan (Axial) in Lab

4.5.2 Axial Air Flow system setup- 02

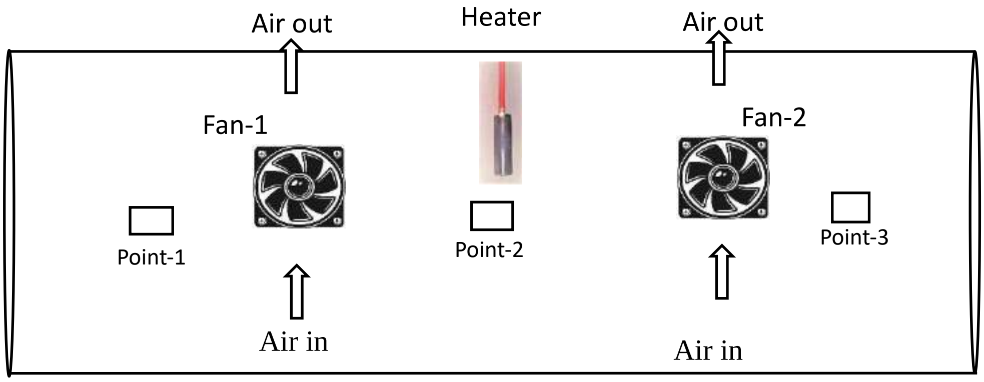

Figure: 4.5.2 Tunnel model with Fan & Heater

4.5.2 Axial Air Flow system setup- 02

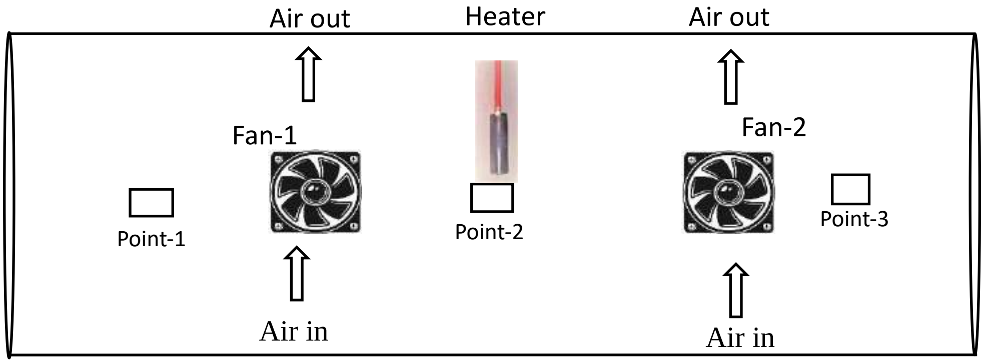

Figure: 4.5.2 Tunnel model with Fan & Heater

4.5.3 Axial Air Flow System Setup- 2

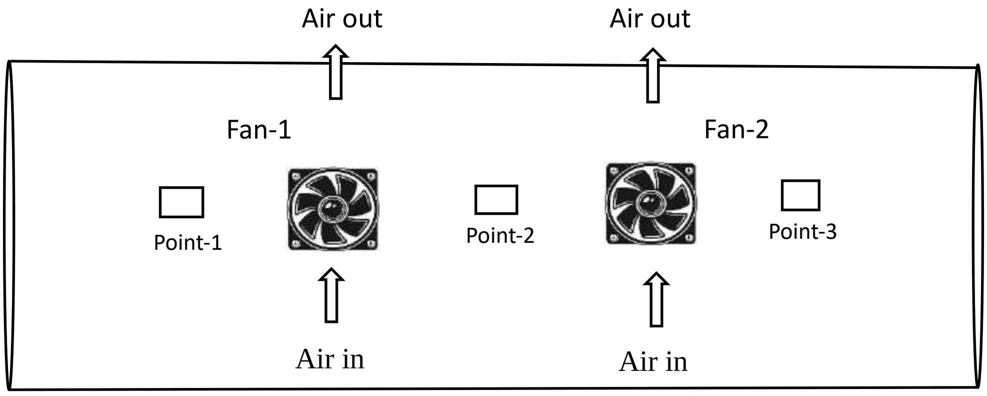

Figure: 4.5.3 Tunnel model with Fan

4.6 PVC Pipe

Polyvinyl chloride pipe made by artificial underground road. Used Pipe diameter 250mm, length 650mm.

4.6 Figure: PVC Pipe

4.7 Insulation

Insulation refers to a material or substance that is used to reduce the transfer of heat, sound, or electricity. It is commonly used in various applications to improve energy efficiency, create a comfortable environment, and protect against external factors. Here is used 13mm thickness insulation.

4.7 Figure: Insulation

4.8 Ventilation Fan

A ventilation fan is a device used to circulate and refresh the air in an enclosed space by removing stale air and introducing fresh air from the outside. It helps in maintaining air quality, controlling moisture, and eliminating odors, smoke, and other pollutants. Here is fan use for underground ventilation system. Air flow 11.5 cfm, Fan size 120mm x 120mm x 40mm.

4.8 Figure: Ventilation Fan 11.5

4.9 Heater

A space heater is a device used to heat a single, small- to medium-sized area. This type of heater can be contrasted with central heating, which distributes heat to multiple areas. Heat generates capacity 120w.

Figure: Heater 120w

CHAPTER 5

Results Analysis

5.1 Parallel l Airflow system Setup- 01

Shown in Figure:4.4.2 Temperature and relative humidity difference from ambient temperature and relative humidity with different Time & point- 1, 2, 3 average temperature and relative humidity.

Table: 5.1.1 Inside Temperature and Relative Humidity Inside Tunnel with Fan (Parallel) and Heater Installed.

Time (Min)	No. of Fan	No. of Heater	Ambient Humidity (RH%)	Average Relative Humidity (RH%)	Relative Humidity Difference (RH%)	Ambient Temp. (^{O}C)	Average Temp. of Air (^{O}C)	Temp. Difference (^{O}C)
5	2	1	73	72	-1	29.4	30.7	1.3
10	2	1	73	72	-1	29.4	30.9	1.5
15	2	1	73	72	-1	29.4	31.3	1.9
20	2	1	73	71	-2	29.4	31.4	2
25	2	1	73	71	-2	29.4	31.7	2.3
30	2	1	73	72	-1	29.4	31.9	2.5

Average Temperature = 31.3^{O}C

Average Relative Humidity = 71.6%

5.2 Parallel Air flow system Setup- 01

Shown in Figure: 4.4.3 Temperature difference from ambient temperature with different Time & point- 1, 2, 3 average temperatures.

Table: 5.2.1 Inside Temperature Tunnel with Fan (Parallel) Installed.

Time (Min)	Number of Fan	Ambient Temperature (^{O}C)	Average Temperature of Air at trunnel (^{O}C)	Temperature Difference (^{O}C)
5	1	28.9	29	0.1
10	1	28.9	29.2	0.3
15	1	28.9	29.2	0.3
20	2	28.9	29.4	0.5
25	2	28.9	29.7	0.8
30	2	28.9	29.9	1

Average Temperature = 29.4^{O}C

5.3 Natural Air Flow System Setup- 01

Shown in Figure: 4.4.4Temperature and relative humidity difference from ambient temperature and relative humidity with different Time & point- 1, 2, 3 average temperature and relative humidity.

Table: 5.3.1 Inside Temperature and Relative Humidity Inside Tunnel with Heater Installed.

Time (Min)	No. of Heater	Ambient Humidity (RH%)	Average Relative Humidity (RH%)	Relative Humidity Difference (RH%)	Ambient Temperature (^{O}C)	Average Temperature of Air (^{O}C)	Temperature Difference (^{O}C)
5	1	70	72	1	28	32.3	4.3
10	1	70	72	2	28	35.6	7.6
15	1	70	72	2	28	37.3	9.3
20	1	70	73	3	28	38.4	10.4
25	1	70	73	3	28	39.4	11.4
30	1	70	73	3	28	39.9	11.9

Average Temperature = 37.15^{O}C

Average Relative Humidity = 72.5%

5.4 Axial Air Flow system setup- 02

Shown in Fig: 4.5.2 Temperature and relative humidity difference from ambient temperature and relative humidity with different Time & point- 1, 2, 3 average temperature and relative humidity.

Table 5.4.1: Inside Temperature and Relative Humidity Inside Tunnel with Fan (Axial) and Heater Installed.

Time (Min)	No. of Fan	No. of Heater	Ambient Humidity (RH%)	Average Relative Humidity (RH%)	Relative Humidity Difference (RH%)	Ambient Temp. (^{O}C)	Average Temp. of Air (^{O}C)	Temp. Difference (^{O}C)
5	2	1	71	70	-1	30	30.9	0.9
10	2	1	71	70	-1	30	31.3	1.3
15	2	1	71	69	-2	30	31.7	1.7
20	2	1	71	69	-2	30	31.9	1.9
25	2	1	71	69	-2	30	32.1	2.1
30	2	1	71	68	-3	30	32.4	2.4

Average Temperature = 31.7^{O}C

Average Relative Humidity = 69.1%

5.5 Axial Air Flow system setup- 02

Shown in Fig: 4.5.3 Temperature difference from ambient temperature with different Time & point- 1, 2, 3 average temperatures.

Table 5.5.1: Inside Temperature Tunnel with Fan (Axial) Installed.

Time (Min)	Number of Fan	Ambient Temperature (^{O}C)	Average Temperature of Air at trunnel (^{O}C)	Temperature Difference (^{O}C)
5	1	28.9	28.9	0.0
10	1	28.9	29	0.1
15	1	28.9	29.1	0.2
20	2	28.9	29.1	0.2
25	2	28.9	29	0.1
30	2	28.9	29	0.1

Average Temperature = 29.01^{O}C

The planned axial airflow system tunnel inside temperature has an ambient temperature difference from the tunnel's average temperature after 5 minutes of natural airflow. Tunnel one side of the top flows air through an axial fan inside the tunnel and the other side of the top exhausts the air outside tunnel, the difference in temperature inside can be observed. It is observed that temperature difference and relative humidity difference due to airflow inside the tunnel, a heater is used to control relative humidity, As a result of using the heater, inside the tunnel increases the temperature. By turning on the heater in the center point of the tunnel, flowing fresh air from one side of the top tunnel, and exhausting air from the other side of the top out to the tunnel, the difference in temperature inside and outside the tunnel can be observed. The fan is used to expel the temperature outside the tunnel. Here the fan is not only used to get the internal temperature out. Fresh air from the outside has been used to the tunnel inside. Flowing tunnel inside & outside temperatures is different. Axial airflow system difference in tunnel temperature relative humidity inside and outside is shown in Fig: 4.4.2, Fig: 4.4.3, Fig: 4.4.4 & Table:5.1.1, Table: 5.2.1, Table: 5.3.1 Values were taken after 5 minutes of natural ambient temperature relative humidity to tunnel temperature relative humidity for this study.

Temperature and humidity differences inside the tunnel were recorded every five minutes for up to thirty minutes. The temperature increased by 2.5, and Relative Humidity -1% has decreased from the ambient temperature.

By turning on the heater in the center point of the tunnel, flowing fresh air from the parallel side of the midpoint tunnel, and exhausting air from the other parallel side of the midpoint out to the tunnel, the difference in temperature inside and outside the tunnel can be observed. The fan is used to expel the temperature outside the tunnel. Here the fan is not only used to get the internal temperature out. Fresh air from the outside has been used to the tunnel inside. Flowing tunnel inside & outside temperatures is different. Axial airflow system difference in tunnel temperature relative humidity inside and outside is shown in Fig: 4.5.2, Fig: 4.5.3, & Table:5.4.1, Table: 5.5.1 Values were taken after 5 minutes of natural ambient temperature relative humidity to tunnel temperature relative humidity for this study. Temperature and humidity differences inside the tunnel were recorded every five minutes for up to thirty minutes. The temperature increased by 2.4, and Relative Humidity -3% has decreased from the ambient temperature. Here it is observed that temperature is lower in the parallel airflow systems than in the axial airflow system. Temperature is higher in the axial airflow system.

CONCLUSION

Heat balance is a dominant factor when required microclimate formation in underground tunnel. Available methods for calculation of unsteady heat losses by underground tunnels take into account such factors as depth of underground tunnel placement, and shape, as well as sub-soil properties etc. with different limitations. One of the problems of the methods is inability of determination of time period shift of maximal/minimal temperature variations and heat losses by underground tunnel relatively outdoor air temperature varied with time including the building dimensions. It makes difficult to control of equipment operation. In the above methods, the air movement in tunnel effecting on inner air temperature

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