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Tunnel Ventilation System-During Construction

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Abstract: During construction of tunnels, different operations such as drilling holes, blasting, mucking, scaling etc. are done due to which poisonous gases are produced in tunnel. To safe guard the workmen, it becomes compulsory to remove these gases and bring inside the fresh air. Workplaces on tunnel sites are exposed to numerous nuisances and sources of health risk. In order to reduce the pollution caused by dangerous gases and dust, tunnel engineers use ventilation systems. This paper describes the various ventilation systems, and their advantages. It discusses natural ventilation methods and mechanical ventilation methods, along with the purpose, qualities and effectiveness so that workmen can perform the job of tunnelling comfortably. Also, the plant and equipment, engaged safely and efficiently, in tunnel construction operations.

Keywords: tunnel, natural ventilation, dangerous gases, dust, equipment, workmen, safely

1.0 INTRODUCTION

Ventilation is required during the construction of any tunnel. This is true whether the tunnel is constructed by blasting, boring or placing prefabricated tubes in a trench. Temporary ventilation is necessary to provide a suitable, safe working environment for the construction workers. Since many flammable or airborne toxic gases, dust mist and fumes are released during the construction process, these contaminants can only be removed by ventilation. A dedicated, well-tailored ventilation system is compulsory in the presence of natural gas in terms of flammability and asbestos in terms of toxicity.

Ventilation systems for construction sites must be flexible in order to grow and move with the construction progress. They may therefore imply rather complex flow pattern including leakage flows, booster stations, filtering and cooling devices, conjunctions and disjunctions etc. Depending on the excavation length and method as well as the geothermal and ambient boundary conditions, cooling of the working environment may also be required. Considerable heat may be transferred to the tunnel air from the rock mass, from the boring machine, other machinery and vehicles as well as from cement setting. Especially heat transfer from the rock-mass is complex, because it is transient in time due to the gradual cool-down of the rock from the tunnel wall. A tunnel should be essentially well ventilated during construction operation

Due to the following reasons:

- To furnish fresh air to workmen at the face of tunnel during construction
- To remove objectionable gases and dangerous fumes produced by explosives.
- To remove the dust caused by drilling, blasting and mucking and other operations.
- To ensure the whole tunnel must be free from the dust and dangerous gas fumes, so that mucking operation are carried out safely

1.1 Ventilation in Tunnels -Types of Ventilation Systems in Tunnel Construction

Here are various types of ventilation systems in tunnel construction provided to remove dust and poisonous gas during its construction and operation. These ventilation systems in tunnel construction are discussed in this article.

The tunnel construction works are mainly carried out by drill and blast method, which have many safety and health issues due to the emission of dust and many poisonous gasses. Hence it is essential to provide ventilation systems in in tunnel during construction.

1.2 The main objectives of providing ventilation systems in tunnel are:

- To provide the working crew an environment of fresh air.
- To exhaust out fumes and gasses, that is injurious to health and explosive in nature.
- To remove the drilling, mucking and blasting gasses emitted.

Ventilation during construction and after completion of tunnel construction is an essential feature that a tunnel should own to facilitate functional, comfortable and a safe tunnel environment for both the road and railway tunnels.

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1.3 Necessity of Ventilation Systems in Tunnel Construction

When the work is being carried out within the tunnel, each worker has to be supplied with fresh air constantly. The consideration of compressed air emitted during drilling purpose is contaminated with oil and dust. So this should not be taken as a source of air to play the role of ventilation. After each explosion, the face is completely covered with air that is full of fumes and dust, which is unfit for breathing. Before he starts to remove the debris of the explosion, the foul air surrounding him must be removed out by any source of exhaustion and get him fresh air. There exist 30 minutes between the explosion and mucking process, within which the ventilation system installed should clear the tunnel contaminated with poisonous gas and dust and refill with fresh air.

There are mainly three factors, based on which the form and capacity of the ventilation system are dependent:

- The length of the tunnel and its size.
- The amount of explosives used for blasting and their respective frequencies
- The condition and rate of temperature and humidity inside the tunnel

2.0 WORKING ENVIRONMENT INSIDE A TUNNEL

The working environment inside a tunnel is contributed by the following factors:

- The dust and the gasses emitted by the tunnelling operations
- Exhaust gasses emitted by the diesel operations
- Explosive or organic solvent emitted poisonous gasses. For example, Nitrogen oxide, hydrogen sulphide, sulphurous acid gas, carbon monoxide
- Flammable gasses or oxygen shortage gas in the ground. For example, methane, carbon monoxide and hydrogen sulphide
- High temperature and humidity factors

Table-1: Density of Dust Emitted due to Tunnelling Works

Tunnelling Works	**The Density of Dust Formed in mg/m^3**
Excavation	10 -1000
Loading of materials that are excavated	10 – 1000
Mucking	10 – 100
Drilling	1-50
Blasting	100 – 300
Shotcreting	10 – 200

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Table-2: Volume of Generated Poisonous Gas in Tunnels

Source	Classification	Poisonous Gas Emitted	Volume of the gas in m^3/kg for Carbon Monoxide and $m^3/(min/piece)$ for Nitrogen Oxide (NO_X)
Explosive	Enoki Dynamite No.2	Carbon Monoxide	8×10^{-3}
	Other Dynamite	Carbon Monoxide	11×10^{-3}
	Slurry type	Carbon Monoxide	2×10^{-3}
	Emulsion Kind	Carbon Monoxide	5×10^{-3}
	ANFO	Carbon Monoxide	30×10^{-3}
Diesel	Shovel	Nitrogen Oxide	55×10^{-6}
	Dump Track	Nitrogen Oxide	20×10^{-6}
	Others	Nitrogen Oxide	20×10^{-6}

The table below shows the allowable density of dust poisonous gas to control the standard values.

Table.3: Allowable Density Value of Dust inside Tunnel

Category	Kinds of dust	Allowable density (mg/m^3)	
		Absorbent dust	Total dust
I	Tale, Soapstone, Kieselguhr, Aluminum, Bentnite, etc	0.5	2
II	Mineral dust, Iron oxide, Coal, Portland cement, Limestone, etc	1	4
III	Other organic or inorganic dust	2	8
Asbestos	Actinolite, etc	0.12	

Table.4: Allowable Density of Poisonous Gas in Tunnels

Gas	Allowable density (ppm)
Carbon monoxide	100
Nitrogen oxide	25

3.0 TYPES OF VENTILATION SYSTEMS IN TUNNEL CONSTRUCTION

The methods employed for tunnel ventilation generally depends upon the normal, emergency or congested operation that will be dependent on the actual conditions of the size, cross section, traffic conditions, intermediate ventilation shafts etc.

3.1 Types of Ventilation Airflow Systems in Tunnels

Longitudinal Ventilation Airflow Systems in Tunnels

Here the direction of airflow is longitudinal in nature. At the beginning of the tunnel or the tunnel section starting, these moves the pollutant gasses and effluents, that is followed by the fresh air. Then at the end of the tunnel portal or at the tunnel section end, the polluted air is discharged. This is shown in the figure-1.

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The configuration of longitudinal ventilation can be either portal to portal, shaft to shaft or from portal to shaft. For transit and railway tunnel, the longitudinal airflow system is used.

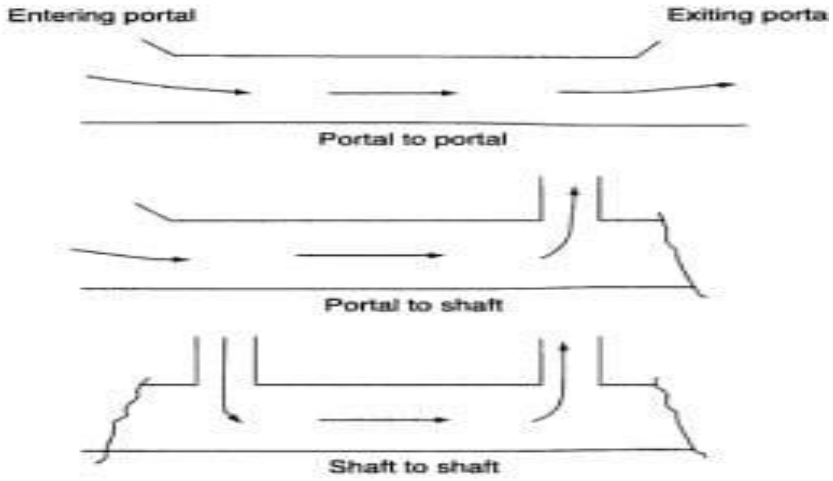

Fig.1: Configuration of Longitudinal Ventilation in Tunnels

3.2 Transverse Airflow Ventilation Systems in Tunnel

Here uniform distribution of fresh air is created along the length of the tunnel. It is mainly employed in road tunnels. Occasionally it is used for transit tunnels. A consistent level of temperature and the pollutants will be maintained if this system is employed. The system can be either fully or semi-transverse.

Transverse or semi-transverse ventilation tunnel is better than a longitudinal one for the tunnels that are longer than 4 to 5 km.

The ventilation system capability and their choice will depend on the air considerations, the amount of air within the tunnel that too must be calculated based on the traffic conditions, the rate of emission of gases within the tunnel, standards of pollution level, the local standard conditions so that the neighbouring environment too is not polluted and harmed.

In the case of railway tunnels, the emergency scenarios of smoke or fire cause is a major concern behind the choice of ventilation. Here mainly longitudinal ventilation is used- that uses ventilation plants at intermediate shafts or at the station adjacent. These may be either combined with exhaust from large caverns.

The ventilation provided can be either **Natural** or **Mechanical** ventilation.

3.3 Natural Ventilation Systems in Tunnel

When from one portal to next portal of the tunnel, there is a provision of drift, it forms a fair ventilation during the operations involving enlarging. This is when the tunnel length is short. In the case of long tunnels, such natural ventilation will be inadequate and we must design separate mechanical ventilation system.

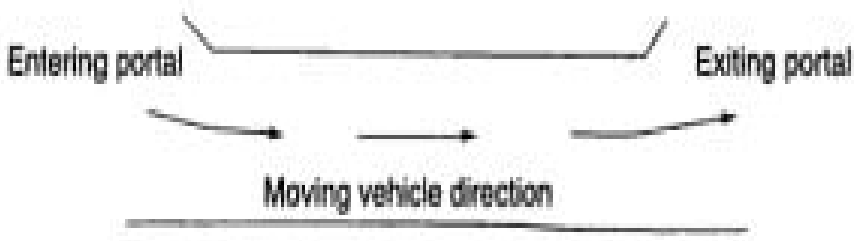

Fig.2: Natural Ventilation Configuration in Tunnels

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The natural ventilation can be configured from portal to portal, shaft to shaft or from portal to shaft. As shown in figure.5. the roadway has an air velocity that is uniform. The temperature and the pollutant level increases at the exit portal or the section end.

If the meteorological conditions of the tunnel go adverse, the velocity, the temperature, and the pollutant level get increased. The pressure differential between the two tunnel portals, that is formed by the differences in the elevation and the ambient temperatures of wind are the chief meteorological conditions. A sudden change in wind direction or the wind velocity will affect the natural effects along with the vehicle generated piston effect.

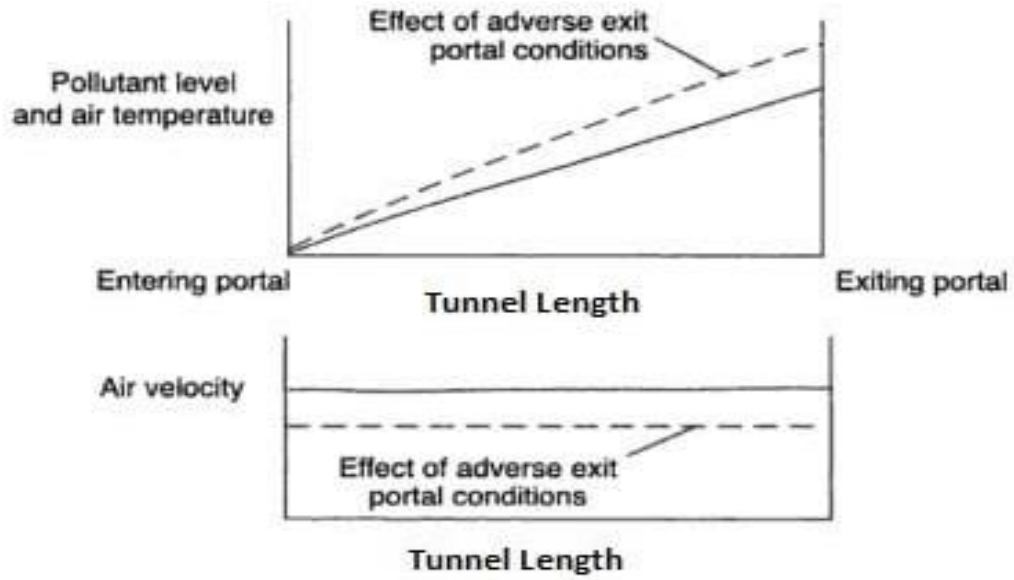

Fig.3: Airflow Characteristics in Natural Ventilation System in Tunnels

3.4 Mechanical Ventilation System in Tunnels

Mechanical ventilation system employs mechanical devices like electric fans, exhaust, and blowers, which serves the function of removing the exhaust gasses within the tunnel and help in blowing fresh air into the tunnel. Now, whatever be the device employed, there are three main services they can provide:

- ❖ Blowing
- ❖ Exhausting
- ❖ Combination of blowing and exhausting

3.5 Blowing Ventilation Systems in Tunnel

As the name tell, fresh clean air is blown to the working face, with the help of pipes. When it flows back to the portal, it takes the dust and gasses with it. This system of ventilation help providing fresh air near the working face with ease. But in long tunnels, these systems have a disadvantage of fogging the atmosphere inside the tunnel when the smoke, dust and foul air move out.

3.6 Exhausting Ventilation Systems in Tunnel

The system incorporates an exhausting duct near the working face, into which, the foul air and the dust are let. By this fresh air is maintained within the tunnel, through the entrance. Quick removal of dust and smoke is one advantage of the exhausting system.

3.7 The Combination of Blowing and Exhausting

The figure below shows a schematic figure of a blowing and exhausting system applied in a combination. This concept is developed, so that the advantage of each system can be combined, bringing a ventilation system of higher performance.

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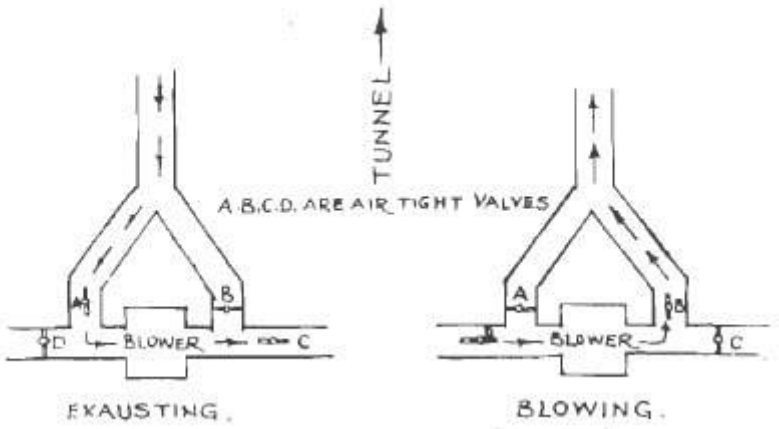

Fig.4: Schematic Representation of Combination of a Blowing and Exhausting Ventilation System in Tunnels

3.8 Working: After the explosion or blasting, the exhausting system will operate for a period of 15 to 30 minutes. This will remove harmful air immediately. After this, the blowing system works continuously to supply the fresh air till the next blasting.
From the figure-4, **D** is the fan and it is supposed to rotate only in one direction. Now the valves **A, B,** and **C** are valves that are manipulated either to exhaust from or blow into the tunnel.

4.0 DUST PREVENTION IN TUNNEL CONSTRUCTION

The dust accumulation within the tunnel is the after effect of conduction the blasting, drilling mucking operations. If the dust accumulated amount is beyond the permissible limit, it creates harmful effects for the people working and to the surrounding environment.
The blasting of rocks as a part of tunnelling operation will emit a high amount of silica in the environment. The intake of same will cause a disease called the “silicosis” which is fatal.

4.10 Dust Control Methods in Tunnels

The methods used to control dust accumulation are:

- Wet drilling
- Use of vacuum hood
- Use of respirators

Now modern drilling machines are available, that make use of water to drill. Here the area that is to be bored is made wet, resulting in a reduction of dust emission.

The figure below shows a vacuum hood that is used in tunnelling work. A hood is fitted to a drill face. This is at the rock face. This is connected to an exhaust pipe. The exhaust pipe takes in the dust formed by the drilling process and that is taken safely out of the tunnel. This reduces no flying of dust to outside.

Another common and efficient method to prevent dust inhalation is using respirators. These are well designed units that are worn by the miners and workers, who are highly exposed to the dusty environment.

5.0 TUNNELLING WORKS SAFETY AND HEALTH

To secure safer and healthier environment during the tunnelling works, it is necessary to take absolute measures while carrying out the operations of drilling, blasting, excavation, concreting and mucking. Dust, smoke and poisonous gasses inside tunnel can be removed efficiently with the help of a proper ventilation. The government has considered this step to safeguard the health and safety of the labour’s working in the tunnel.

In Tunnel work 4.25 cu. meter of air/minute/man is usually considered the minimum requirement. In addition to the 2.00 cu. meter of air/minute shall be applied for such break horse power of diesel locomotive or other diesel engine used in the tunnel.

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6.0 CONCLUSION/RECOMMENDATION

❖ Circulation ventilation is aerodynamically the best choice, as flow leakage is no issue and friction is low because the plain sections of the tubes are used. Also, the ventilation equipment costs are low.

❖ Forced ventilation schemes are rather cheap, as standard flexible ducting can be used. This equipment is on the other hand not particularly tight, resulting thus in high power requirements due to the rather important leakage flows.

❖ Exhaust ventilation is expensive in terms of capital costs, as several booster stations are required and spiral steel sheet pipes must be installed. Power consumption on the other hand is moderate and the scheme is compatible with standard requirements,

❖ The ventilation system must be designed to provide adequate levels of ventilation from face to portal throughout the tunnel during construction.

❖ The ventilation should include the provision for additional localised ventilation to deal with ground gases, production of dust, heat or fumes from the excavation process, operation of large plant or other activities such as maintenance.

❖ The design should allow for the need to install ventilation as the tunnelling progresses to maintain ventilation to the face**.**

❖ Tunnelling engineers in charge shall pay much attention to environment in tunnel,

❖ Research geology, select the excavation method to minimize the negative impacts and design the appropriate ventilation system in tunnel during construction.

❖ The facilities and equipment for the safety and health including the ventilation system

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BIOGRAPHY

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