Impact of Tunnels in Environment

N. Aruna kumari #1, Subhajit Paul*2

Assoc.Prof#1
#Dept. of HBS#1
Department of Civil Engineering *2
Godavari Institute of Engineering & Technology
Rajahmundry, Andhra Pradesh, India

Abstract: Many research works are going on to save or protect the environment from different hazardous or toxic gases, chemicals and other harmful effects. Different construction materials (both renewable & non-renewable) are used while constructing any structure, road, railway, tunnel, etc. But every Engineer must know the concept of sustainable development and the particular application of construction materials in its related areas without effecting the green environment. To satisfy the needs, huge rush, demands, time saving etc., of people in roadways, Traffic or Road Tunnels are constructed. In this paper the importance of ventilation in construction of tunnels is highlighted as because different harmful or toxic gases or chemicals are generated by the vehicles passing through it. The aim of this paper is to bring the awareness about the tunnel environment while constructing Tunnels and to minimize the hazardous effect inside the tunnel and also to the environment.

Keywords: Tunnels, Purposes of tunnelling, Road or Traffic Tunnels, protection of environment, harmful or toxic gases, Tunnel Ventilation.

I. INTRODUCTION

All the things that surround us are known as Environment. The surrounding conditions, influences, or forces that influence or modify as:

a) The whole complex of climatic, edaphic and biotic factors that act upon an organism or an ecological system and ultimately determine its form and survival.
b) The aggregate of social and cultural conditions as customs, laws, language, religion, economic and political organization that influence the life of an individual or community.

Environment to an Engineer would mean a set of standards and recommendations that he must comply with and threshold the values that must not be exceeded. His technical solutions would be developed keeping in mind that the inevitable outputs as noise nuisance, waste or effluents do not hamper or affect the living and working conditions inside and outside the process that he is designing or operating. But, environment would also mean that he should pay attention on safeguarding the natural resources by using as much as possible of the renewable energy sources and recycled materials, and strive to achieve a long-lasting development which mainly focuses the “Green & Sustainable Environment”.

II. OBJECTIVE

The objective of this paper is to focus on the urban road tunnels, the ventilation of which directly concerns the environmental problems. Ventilation is precisely designed as well as operated to make or provide a user friendly atmosphere inside the tunnel i.e. clean, healthy and pleasant for the user keeping in mind that the surroundings of the tunnel should not be overlooked and the environmental conditions near the tunnel portals must be preserved. This is mainly observed in urban sites. Moreover, controlling the discharge of pollutants through chimneys or exhaust openings in the ceiling is also an important issue.

This paper covers the brief introduction of the following:

a. Tunnel
The horizontal underground passage open at both the ends to the ground surface is known as “Tunnel”. The construction of tunnels mainly takes place below the cities, rivers, and through mountains by the removal of overburden, making cuts and then laying roof slabs.

There are mainly three different types of tunnels. They are:

1. Traffic or Road Tunnels
2. Hydro-Power Tunnels
3. Public Utility Tunnels

This paper fully deals with the “Traffic or Road tunnels” and its proper ventilation from any harmful or hazardous effect.

b. Purposes of tunnelling:
There are many purposes of tunnelling. Some of them are as follows:

1) They are excavated across the hills and highlands to lay roads or railways.
2) Underground tunnels reduce the distance across natural obstacles like hills or mountains which save the time and also provide convenience.
3) Pressure tunnels allow water to pass with force and generate power.
4) For supply of drinking water public utility tunnels are drawn.

c. Traffic or Road Tunnels:
Building of road tunnels today is a matter of responding to the unavoidable problem due to the ever increasing traffic volumes mainly in densely populated areas. Besides the psychological and stress aspects, driving through tunnels adds new problems to the one that is already created by traffic on open roads. The new problems concerned include:
a. Air pollution with frequent health hazards,
b. Absence of escape lanes which constitutes a severe risk for people who have to stop their cars,
c. Reduced visibility that causes higher accident rates.
d. Fire hazards and subsequent smoke development which could be a real threat in tunnels, etc.

In order to create a healthy and safe environment in tunnels, one has to maintain a high standard air quality, good visibility, an acceptable noise level, and reduce as much as possible all potential hazards by carefully designing the tunnel management system. This goal is achieved mainly by:
a. Identifying correctly the different characteristic parameters of traffic flow, such as speed, concentration, congestion and presence of stopped cars.
b. Based on this traffic information, predicting the forthcoming pollution,
c. Acting subsequently on the mechanical ventilation equipment (injecting and extracting fans, jet-fans etc.,) in order to maintain the required air quality level, yet at minimum energy costs,
d. Detecting or, determining instantaneously, various kinds of hazards.
e. Taking adequate or proper decisions by dispatching the alarms according to some priority rules, sending effective and efficient messages to the user, if and when needed.

Since the complexity of tunnels is increasing day by day and users are more demanding, especially when their health and safety are concerned, there is an urgent need to install sophisticated and expensive equipment such as high-sensitive pollution meters, fire detection systems, traffic sensing devices and video cameras. Unfortunately, most of this equipment, sometimes installed at different life stages of the tunnel, operates in a stand-alone mode, the first concern being only the display of the measured data. Moreover one could gain more from these valuable measurements and information by integrating them into a single processing system, making not only the expenses more profitable, but there could also be other benefits too, such as:
2) Information of different nature and origin, processed together may increase the reliability of the system, and hence reduce false alarms,
3) Part of the operator’s decision making may be supported by proposals issued by an artificial intelligence processing unit, known as “Expert system”.

4) Operational ventilation costs due to pollution could be reduced, either by controlling the traffic through changeable road signs and variable message panels, or by anticipating certain actions on the ventilation. In the latter case, traffic data would be processed together with pollution measurements. The calculated pollution trend could then help to predict the forthcoming concentrations, thus enabling to smooth out critical pollution peaks by anticipating the necessary actions on the fans.

IV. DIFFERENT SOURCES OF POLLUTION

Traffic is undoubtedly one of the important sources of environmental and air pollution. It does not only have a harmful impact on health but also indirectly affect the quality of life by disturbing the eco-system, destroying our natural beauty, cultural inheritance, and many more. Despite of all the efforts and all kinds of recommendations to reduce, especially in large cities, both traffic flow and one of its first nuisances, i.e. the pollutant emissions, it may be expected for the next few decades that traffic will remain an important source of pollution. Therefore a lot of money has been invested in installing the monitoring equipment, developing data transmission networks and building supervision centers.

The combustion of fuels in vehicles like gasoline, LPG, CNG, petrol, diesel etc., and engines produces a lot of toxic substances which affects the environment a lot. Depending on their concentration, their chemical stability and their adverse effects on environment and human being, the most relevant compounds in the exhaust gas are:

SO2: The production of SO2 due to the traffic is related to the sulphur content of the fuel. Today, diesel contains a mass concentration lower than 0.2%. For gasoline it is even lower and for LPG it is virtually zero. Since the traffic contributes only 5% of the total SO2 emission, the possible presence of this pollutant is usually not taken into account as far as tunnel ventilation is concerned.

CO2: This compound is the main product of the combustion of a fossil fuel. The substance is not directly responsible for health damage, but is responsible for the “greenhouse effect”. Although a non-negligible amount of the produced CO2 has to be taken on account of the traffic, the problem has a world-wide extent which is not specific to tunnel ventilation.

CO: This pollutant is produced in a reducing atmosphere, either by an overall shortness of the combustive or by a local deficiency due to the non-homogeneous character of the mixture of fuel with air. By experiments, spark ignited engines produce more
CO at lower speeds. The introduction of a catalyst, however, drastically reduces the emission of CO by a factor of 10.

NO\textsubscript{2}. The mixture of NO and NO\textsubscript{2}, of which the latter is a very toxic substance, is often referred to as NO\textsubscript{2}. Experiments showed that traffic contributes for about 60% to the entire NO\textsubscript{2} pollution. At high temperatures, its two main compounds combine to form NO (together with small amounts of N\textsubscript{2}O) and this reaction is sufficiently fast enough to produce a measurable quantity. On the other hand, the cooling down after the combustion process is too fast to allow a reversible dissociation of NO into its two compounds. A small amount of this NO is then transformed by oxidation into NO2 at the exhaust pipe of the vehicle. The mutual interactions of the triangle NO, NO\textsubscript{2} and O\textsubscript{3} in a pure atmosphere under the influence of solar light irradiation is already very complex. But, if we additionally take into account that other polluting free radicals such as (CHO)-, (OH)- and (HO\textsubscript{2})- are present or produced in exhaust gases, then the production of NO\textsubscript{2}, together with some other pollutants and fog, becomes extremely complex and may involve hundreds of problems. The rate of oxidation is mainly dependant on the NO concentration, and thus the formation of NO\textsubscript{2} is favored by a higher pressure and a lower temperature (<160°C).

III. VOLATILE ORGANIC COMPOUNDS (VOC)
Unpleasant environment often reported in some tunnels which makes one assume that pollutants other than CO and NO\textsubscript{2} must be present in the air. Among them we can identify substances such as aromatic and aliphatic hydrocarbons that are produced by the vaporisation of the in combusted liquids and their partially burnt compounds C\textsubscript{n}H\textsubscript{2n+2} as a residue of incomplete combustion. Usually, these HC’s are measured as a whole, mostly by a technique of “Flame Ionisation” (FID).

Congested traffic situations with a lot of accelerations will gradually increase this kind of pollutant production.

Particles generated by VOC:
They constitute a different kind of pollution. Although some of them, such as polycyclic aromatic hydrocarbons are known for their cancer producing effects and asbestos for causing malignant pneumoconiosis, their presence, after a certain concentration, has mainly the inconvenience of reducing visibility.

“Toxicity” is defined by “Lauwerys”, as “The capacity inherent in a substance of producing a hazardous effect on the living organism”. One could define “Toxicity” as a limit above which the organism is no longer capable of neutralising the permanent influence of the considered substance without leaving visible irreversible damage, so-called after-effects. These substances of course cover a lot of different meanings and almost each of them acts in a different manner on the human body. Tolerated quantities are also being given by the scientist Lauwerys.

V. VENTILATION
The process of passing fresh air into any closed area like rooms, tunnels etc. for providing a pleasant atmosphere inside is known as “Ventilation”.

Ventilation is mainly of two types:
1) Natural ventilation,
2) Artificial ventilation.

Tunnel ventilation:
Ventilation which is being provided in the tunnels for providing pleasant atmosphere inside is known as Tunnel ventilation.

Tunnel ventilation systems can be classified into three basic ventilation schemes,
1) Longitudinal,
2) Transverse and
3) Semi-transverse ventilation.

Longitudinal ventilation in Tunnels:
The principle of the longitudinal ventilation is to favour the natural draft by acting in such a manner that the mean air flow velocity has a sufficient value. For this purpose, one or more jet-fans close to the walls or the ceiling are installed that provide the necessary driving force. This kind of ventilation system is particularly suitable for one way traffic, i.e. the air is blown in the same direction in which the traffic goes. With regard to pollutant concentrations, their maximum values are to be expected at the tunnel exit, or, if several sections are present, at the end of each section. The growing rate of course is a function of the amount of emitted pollutants which, for a constant traffic flow it may be assumed to be approximately constant.

Transverse ventilation in Tunnels:
Inlet, as well as outlet air, is ducted along the tunnel. It is blown into the tunnel through more or less equally spaced openings (slots) along one of the walls. The vitiated air is sucked off at the opposite wall also through equally spaced openings and let into a collecting duct. In this manner the air will theatrically flow perpendicular to the axis of the tunnel and also to the traffic. Therefore, this ventilation scheme is particularly suitable for all kinds of traffic and for long tunnels. Of course, the air volumes that are supplied and sucked off may be different, this allows a number of combinations. Since the air moves transversely to the traffic, one can expect that the pollutant concentration over the entire length of the tunnel will be nearly constant, certainly if the longitudinal velocity component of the air flow is reasonably low.

Semi-transverse ventilation in Tunnels:
This ventilation scheme is considered as the combination of both the transverse and longitudinal ventilation system. The fresh air is supplied through
openings in the walls or the ceiling, and the vitiated air flows along the tunnel and leaves it through one of the portals according to the combined action of the pressure difference between them and the piston effect. If there is no driving force available that would create a longitudinal velocity component, then the tunnel air flow would be zero in the middle and maximum at both the portals. Depending on the extend of the longitudinal driving force (piston effect, wind, etc.) the resulting zero point velocity would shift along the longitudinal direction until it leaves one of the portals. Assuming the traffic flow and speed to be constant, is not very realistic. The above basic ventilation schemes may also give some indications about the suitable locations where the measurement devices should be installed for higher efficiency.

VI. AFFECTS ON THE SURROUNDING & ITS PREVENTIONS

Due to the closed structure the airborne pollutant concentrations in the tunnel are much higher than the open road, even in severely polluted areas.

The uncontrolled discharge of vitiated air through portals & roof openings or short chimneys makes the pollutant concentrations in the surrounding area to exceed the limits. Mainly for longitudinal & semi-transverse ventilation system, solutions can be applied:

1) Diluting the tunnel air before leaving the portals by adequate fresh air supply.
2) Providing a chimney through which, most of the tunnel air is extracted.
3) Cleaning the tunnel air from certain pollutants by offline filter and precipitating system.
4) Designing the portal geometry to favour the dispersion of pollutants, several studies are carried out in order to evaluate the impact of the tunnel air discharge on the environment & surrounding residential areas.

Speed and flow volume of traffic and pollution control:
Since traffic is the main source of pollution in a road tunnel, the measurement of certain traffic parameters has to be taken firstly. The traffic flow volume, i.e. number of vehicles per unit of time, and the traffic speed in km/h, are measured by analysing the successive pictures of the traffic taken by video cameras. A correct prediction scheme of the traffic flow volumes would certainly be the most adequate application in the scheduling of ventilation fans. It is believed that accurate predictions of the traffic flow volume will both reduce the ventilation costs and improve air quality.

Pollution can be controlled by:

CO Pollution meter: This device uses the well proven non-dispersive infrared (NDIR) absorption technique, which is capable of operating on a real time basis. CO absorbs infrared in a very specific manner, producing an absorption spectrum.

NO2 Pollution meter: The sensor is based on the physical principle of chemiluminescence. NO molecules are oxidized by the chemical reaction between ozone and NO. This reaction gives a light output that is proportional to the quantity NO2 being produced and thus also to the initial NO quantity present.

The instrument itself is not installed in the tunnel but behind its walls. The actual measurement is done on the basis of samples continuously taken by a small pump system.

VII. MECHANICAL EQUIPMENT USED FOR VENTILATION

Mainly used mechanical equipment for ventilation of tunnels is Fans & Jet-fans. These are discussed below:

Fans: The fans used in the tunnel are axial, with variable pitch angle, equipped with a damper. They are set up in group of two fans which are operated in parallel & each pair is controlled by a single operating unit. The calculated ventilation capacity of each fan is approximately 50% of the estimated capacity in case of fire. Other than the maintenance advantage, these also helps to run one fan & then the other alternatively at maximum efficiency. The single control unit helps to monitor the different information coming from the fans like heating problem of bearings, protection against overload of the motor, start & stop procedures, openings & closings of the dampers, & the pitch angle settings in order to match the required air flow quantity.

Jet-fans: Always it is not possible to install air injecting slots where needed, thus jet-fans are distributed along the tunnels for sufficient ventilation at its section. They are again sub-divided. When full-ventilation is not needed, these sub-divisions have the advantage of operating one fan within the same group, hence operating them in alternate manner.

VIII. CONCLUSION

When any construction is done, the main thing that should be focused is balancing of the green environment from any hazardous effect or from any harmful gases. With these considerations in view, the tunnel ventilation control system may make use of the following measurements:

- Concentration of the different pollutants in each part of the tunnel.
- Proper utilisation of the natural resources.
- Through flow rates in the tunnel sections.
- Mean speed and traffic flow in each section.
- Wind velocity and its direction.
- Alarm-signals of smoke and fire detectors.
- There should be proper filtration process of the harmful gases.
- The materials used should be eco-friendly.

If all these aspects are kept in consideration then the hazardous effect to the green environment can be
prevented and minimized and at the same time sustainable development can also be achieved.

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