IV. VENTILATION CONTROL

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Problem Statement

There are two principal aims of a well designed ventilation control system :

- in routine operations, to provide fresh air at a rate that is consistent both with the comfort of the tunnel users, and with economical operations i.e. at the minimum rate for an acceptable level of air quality;
- in exceptional circumstances or emergency cases (equipment breakdowns, accidents or fire in the tunnel), the ventilation system must be capable of responding quickly and reliably to each specific ventilation demand.

Where routine ventilation is concerned, an optimal air flow rate is one that satisfies two conflicting requirements; the rate of ventilation must be sufficient to dilute the pollutants generated by the vehicles, while at the same time the air flow quantities should be as small as possible in order to reduce the energy consumption at the fans and therefore reduce running costs.

The constant adjustment of air flow to cope with the needs is a difficult problem especially in the case of long and complex tunnels where the control of the ventilating airflows can be difficult to maintain.

Emergency ventilation, on the other hand, needs fast and well targeted interventions, short response times, and a well defined sequence of all the operations. The objectives of incident ventilation are therefore quite different from those of normal ventilation, and economic considerations are no longer the principal concern.

The aim of the following text is to review possible solutions for ventilation control.

Control based on Pollutant Concentration

So far, almost all ventilation control systems are driven by the measurement of pollutant concentrations, of which the CO-concentration, and for long tunnels with heavy traffic the opacity, are the only ones to be used as control variables.

This system encounters the following difficulties:

(i) Measurement reliability
For some pollutants such as for example NO_2 there is a real difficulty in measuring their concentration due to the lack of reliable industrial equipment.

(ii) Measurement device location

Measurements are made in several points in tunnel, and the use of these measurements raises two major problems; some measurements are not always representative of the mean level of pollutants and in the case of complex tunnels control must be global and cannot be set out by section without running the risk of transferring pollutants from one section of the tunnel to another, and of control instability.

(iii) Response time

In the case of variable traffic flow rates, the tunnel volume introduces an inertia that causes a delay in measuring the new pollution levels. This phenomenon leads to delayed responses that do not allow economical operation.

(iv) Ventilation stability

Pollution varies constantly with time and space. The control system should produce stable responses to avoid mechanical fatigue of the ventilation equipment and to avoid the frequent starting of fans and their associated large starting currents.

Alternative Control System

An alternative solution to the control based on pollution measurements is to use directly measured traffic characteristics as control variables for setting the ventilation system, pollutant flows being directly linked to the traffic.

The principle is as follows:

- measurement of the traffic before entering the tunnel, or if this is not possible, in different sections of the tunnel
- calculation of the required ventilating air flow
- evaluation of natural ventilation
- determination of the air-handling capacities of the tunnel ventilation fans.

Traffic measurements (flows, speed, type of vehicle) are easily made using inductive loops, video imaging, etc.

Emission rates can be evaluated as a function of these data and of the geometry of the tunnel using data given by PIARC [10].

The evaluation of the appropriate ventilation rates can be made by air speed measurements, comparing real conditions to theorical conditions resulting from the ventilation generated by traffic flows, and by the action of the tunnel ventilation fans.

Conclusion

Control principles based on a description of the traffic that uses the tunnel avoid the difficult task of pollutant measurement and allow immediate control of the ventilation system as soon as traffic variations are confirmed.

It is not linked to a given pollutant but could take into account all pollutants emitted by the traffic.

It is easy to predict, to set, and to modify, the ventilation levels. The control algorithms can also be updated from time to time in line with developments in vehicle emission and regulations or recommendations.

Of course it is necessary to maintain some atmosphere control device to oversee the threshold levels at safety point of view or in case of specific incident.

Reference

[10] Road tunnels, emission, ventilation, environment. Committees on Road Tunnels PIARC 1996 (Montréal), 05.02.B.