Advisory Committee
on Tunnel Air Quality

TP09:
Evolution of road tunnels in Sydney

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Summary

The NSW Government has over 20 years of experience assessing and operating road tunnels, with five tunnels in operation in Sydney with extensive ventilations systems and stacks. There have been some important lessons learnt from the assessment, design and operation of the M5 East and other Sydney tunnels, including:

- The modelling and assessment processes for stack emissions are well established, robust and conservative.
- Emissions from well-designed stacks have negligible impact on surrounding communities and, as such, there is little health benefit in installing filtration and air treatment systems.
- There are a number of lessons that can be learnt from the construction and operation of the M5 East, Lane Cove and Cross City tunnels that will enable future tunnel projects to have an efficient ventilation system that delivers a good user experience:
    - Minimising the gradient of the tunnel
    - Locating ventilation stacks close to entry and exit points
    - Designing entry and exit points to reduce congestion
    - Regulation and elimination of smoky vehicles
    - Increasing the clearance height and width of the tunnel

1. Introduction

Sydney has five long motorway tunnels with substantial ventilation systems incorporating ventilation stacks. They are (and year opened):

- Sydney Harbour Tunnel – 1992
- Eastern Distributor – 1999
- M5 East – 2001
- Cross City Tunnel – 2005
- Lane Cove Tunnel – 2007

Some community groups have expressed concern about major tunnel projects over the years partly because of the potential impacts on air quality. Successive NSW Governments have responded by subjecting these tunnels to detailed environmental assessment prior to approval, and extensive monitoring of in-tunnel air quality during operation.

The effectiveness of ventilation stacks in dispersing emissions from the M5 East, Cross City and Lane Cove tunnels have been measured as part of project approval conditions which required extensive ambient air quality monitoring to ensure that residents in surrounding areas experience little, if any, increase in exposure to vehicle emissions.

NSW Government agencies now have over 20 years of experience in assessing and operating these long tunnels. There were both successes and mistakes and many lessons have been learnt and applied along the way. Agencies are able to draw on the experience from recent tunnel projects in the design and development of new tunnels.

This paper highlights the key lessons learnt from this experience relating to the assessment, design and operation of ventilation systems to manage air quality in and around tunnels.

2. Lessons learnt

Predicting the impact of stacks

The predictive air quality modelling for tunnel stacks is robust and conservative. For more information see Technical Paper 5 – Road Tunnel Stack Emissions.

It has been demonstrated across multiple road and industrial projects that there is sufficient knowledge and experience to tailor stack dispersion modelling for the specific characteristics of each project. (see Technical Paper 5 – *Stack operation and performance*)

Effectiveness of stacks in dispersing emissions

Even when apparently still, the atmosphere is very dynamic and the air is constantly moving. Stacks work by exploiting this turbulent mixing to efficiently disperse pollutants. This point has been recognised by air quality scientists and air pollution engineers for decades, and has led to the widespread adoption of the stack as a means of reducing the ground-level impact of atmospheric releases.

Discharging vehicle emissions via well-designed stacks ensures that they are dispersed and diluted so that there is minimal or no effect on local ambient air quality. Modelling and monitoring studies generally agree that the impacts of emissions from road tunnel stacks on their surrounding communities are mostly indistinguishable from the impacts from all other sources (principally surface traffic emissions, domestic and industrial emissions, and background contributions, including natural sources) (NHMRC, 2008).

As an example, modelling by CSIRO using actual emission data from the M5 East tunnel predicted the maximum contribution of the stack to annual average concentrations is less than 1 per cent of background for PM_{10}, and less than 3.6 per cent of background for NO_x (Hibberd, 2003) at a distance of 600 to 700 metres from the stack[1]. These predicted levels would not be measureable by ambient monitoring equipment.

Extensive ambient monitoring around motorway tunnels such as the M5 East, Lane Cove and Cross City tunnels demonstrates that tunnel stack emissions do not have a measurable impact on local or regional air quality.

Filtration and tunnel air treatment

Emissions from well-designed road stacks have negligible impact on surrounding communities and, as such, there is little health benefit in installing filtration and air treatment systems in such tunnels. Numerous measures have been identified that are both cheaper and more effective at improving air quality than road tunnel filtrations.

An 18 month trial of filtration of tunnel air was conducted in the westbound tunnel of the M5 East from March 2010 to September 2011. The filtration plant removed 200 kg of PM per year at a cost of \$760,000 or \$3,800,000 per tonne (operating costs only) (AMOG, 2012).

The then NSW Department of Environment Climate Change and Water (DECCW) engaged Sinclair Knight Merz to undertake a study to identify and analyse a range of emission abatement initiatives (SKM, 2010). In the Sydney Region, SKM identified 12 emission-reduction measures over ten times cheaper than tunnel filtration, with costs ranging from \$1,000 per tonne to \$274,000 per tonne of PM_{10} removed. For more information see Technical Paper 8 – Options for treating road tunnel emissions.

1 The greater contribution of NO_x reflects that motor vehicles contribute a much greater proportion of NO_x than PM emissions.

This is consistent with the conclusions of the National Health and Medical Research Council that the most effective way to manage air quality both in and around tunnels is through vehicle fleet emission reductions (NHMRC 2008).

Tunnel ventilation system design

It is important for community acceptance of road tunnels as an effective transport solution that tunnels are designed and operated to deliver a good user experience. It is fair to say that, particularly in the first years after opening, the M5 East did not deliver a good user experience. In light of this, the Lane Cove and Cross City tunnels were designed to ensure that in-tunnel air quality met community expectations. However, in practice the Lane Cove and Cross City tunnel ventilation systems have proved over-designed, and the approval conditions have resulted in inefficient operating regimes.

There are a number of lessons that can be learnt from the M5 East, Lane Cove and Cross City tunnels that will enable future tunnel projects to have an efficient ventilation system that delivers a good user experience:

Minimising the gradient of the tunnel

The M5 East has a gradient of eight per cent at the exit of the westbound tunnel. The increase in gradient resulted from a late design change to facilitate the placement of tunnel spoil between Bexley Road and King Georges Road. This was to substantially reduce the number of truck movements on local roads during construction.

The unintended consequence of this change was that vehicles exiting the west bound tunnel are under significant load with multiple consequences for air emissions. Firstly vehicle emissions per distance travelled significantly increase with increase in grade. This is especially the case for ladened heavy vehicles (eg trucks returning from the port). Secondly the steep grade slows down heavy vehicles which contribute to congestion throughout the west bound tunnel further adding to vehicle emissions as compared to free flowing traffic. Consequently the Cross City and Lane Cove tunnels were designed to minimise gradients.

A key design requirement for new road tunnel projects is to minimise grades.

Locate ventilation stacks close to exit points

In order to address strong community concern regarding the location of the proposed three stacks for the M5 East the ventilation system was redesigned to recirculate the tunnel air to a single stack 900 metres from the tunnel alignment. The consequent design is inefficient using significantly more energy than equivalent tunnels operating with ventilation stacks located near the portals.

The most energy and cost effective location for stacks is at or near to the tunnel portals, the reasons for this include:

- Fully uses the piston effect of traffic pushing air through the tunnel and avoids the use of additional energy to pull air though a service tunnel to a remote stack location.
- The stack can be built into the cut and cover structure of the portal and therefore an additional building for ventilation is not required. (see separate paper on Tunnel ventilation system design and operation and energy use).

Designing entry and exit points to reduce congestion

Smoothing traffic flows at the entry and exit points avoids congestion, improves user experience by shortening the length of time in the tunnel and reducing vehicle emissions within the tunnel. The Lane Cove Tunnel was built with two lanes entry and three lane exit to facilitate smooth traffic flow within the tunnel.

Regulation and elimination of smoky vehicles

A common complaint of M5 East tunnel users is being stuck behind a smoky vehicle. Reducing the number of smoky vehicles would not only decrease emissions, but would improve the tunnel user experience.

The M5 East Smoky Vehicle Enforcement Project started on 1 March 2013, and includes increased fines for the operators of smoky vehicles. The smoky vehicle camera system in the M5 East tunnel detects, identifies and records smoky vehicles using smoke detectors, video and still cameras, and optical character recognition software to capture the registration number of smoky vehicles. For more information on the Smoky Vehicle Enforcement Project please see technical Paper 7 – Options for Reducing In-Service Vehicle Emissions

Increasing the clearance height and width of the tunnel

Sydney's tunnels have traditionally been built with a tight cross section to minimise construction costs and spoil generation. This had two unintended consequences. The first was the small cross section of the tunnel increases the friction for any given volume of air flowing through the tunnel than a larger cross section resulting in greater energy requirements for ventilation. Secondly lower clearance height compared to the adjacent network results in a greater frequency of over-height truck incidents resulting in tunnel closures and network congestion.

The Northconnex project is proposing to increase the clearance height and width of the tunnel. Increasing the cross sectional area of the tunnel will also improve user experience by creating a greater sense of space.

3. References

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