ROAD TUNNEL VENTILATION IN NORWAY

This report was prepared at the conclusion of a visit by the Roads and Traffic Authority of New South Wales, Australia to Norway. The visit, which took place from 27-31 September 2001, included inspections in Oslo, Laerdal, Trondheim and Drammen. The visit was hosted by the Norwegian Public Roads Administration.

Overview of roads in Norway

Norway is a difficult country in which to build and maintain roads. It is sparsely populated with rugged mountains and many deep fjords, particularly on the west coast.

Norway has about 91,500 kilometres of public roads. This comprises about 27,000 kilometres of national roads, 27,000 kilometres of county roads and 37,500 kilometres of local roads.

The Norwegian Public Roads Administration (NPRA) is the key body involved in planning, construction and operation of the country's roads. The NPRA manages national and county roads, with a national office based in Oslo and 19 county offices.

Tunnels in Norway

Norway is an acknowledged world leader in tunnelling. Tunnels are an essential part of the Norwegian road system, largely because of the mountainous terrain. In rural areas, they provide more direct and more convenient routes than surface roads. A significant number of tunnels also operate in urban areas, particularly in the major cities of Oslo, Bergen and Trondheim.

Norway has more than 900 road tunnels, covering a total distance of almost 600 kilometres. About 35-40 kilometres of new tunnels are constructed each year. Of the world's 100 longest road tunnels, 25 are in Norway. This includes the world's longest tunnel – the Laerdal tunnel, which runs 24.5 kilometres between Laerdal and Aurland.

Ventilation in Norwegian tunnels

Most road tunnels in Norway are longitudinally ventilated, with air expelled at the portals either naturally or driven by fans.

In 1989, Norway began a research program to determine the possibility of cleaning air in road tunnels. The two key factors in the program were air emissions at tunnel portals and a problem unique to Norway – the widespread use of studded tyres in winter. The tyres cause large amounts of airborne dust, providing significant problems for visibility in tunnels.

Norway's road tunnel air treatment program has involved the use of electrostatic precipitators (ESPs). ESPs are designed to electrically charge dust particles and remove them from the air on collector plates. Three principal different types of layout for the ESPs have been used in Norwegian road tunnels: ESPs in a ventilation shaft connected to the tunnel, ESPs in a bypass area adjacent to the tunnel and ESPs in the tunnel ceiling.

ESPs have been installed in seven road tunnels. Five of the tunnels are currently carrying traffic; two are currently under construction, with one to open later in 2001 and the other in 2002.

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Norwegian road tunnels with ESPs

Festning Tunnel, Oslo

The Festning Tunnel is 1.8 kilometres long and opened in 1990. It is a six lane twin-tube tunnel ventilated by two 20-30 metre tall ventilation stacks and portal emissions.

Air treatment was not part of the original plan for the tunnel. A decision to install ESPs in the base of one of the ventilation stacks was taken during construction of the tunnel as the first Norwegian experiment in cleaning tunnel air.

The filtration equipment has not operated for a number of years.

Granfoss Tunnel, Oslo

The Granfoss Tunnel is 2.3 kilometres long and opened in 1992. It has two one-way traffic tubes.

A decision to install air treatment equipment was taken by the NPRA based on advice from NILU because of concerns that air quality standards associated with the tunnel would not be met.

The ESPs are not operating.

Ekeberg Tunnel, Oslo

The Ekeberg tunnel is 1.4 kilometres long and opened in 1994. It has two one-way traffic tubes.

During the planning of the tunnel, strong community objections were raised over a proposed ventilation stack. The NPRA decided to install ESPs in bypasses in both tunnels because of concerns about breaches of potential air quality goals and because the move was considered more economical than a ventilation stack.

The ESPs are operated by a timer that switches them on during the morning and evening traffic peak periods for a total of four hours a day each business day. The ESPs were planned to treat 50 per cent of the tunnel air 65 per cent of the way along the tunnels, with a theoretical 25 per cent net effect at the tunnel portals. Due to difficulties measuring air quality outside the tunnel portals, there has been no assessment of the impact of the ESPs on air outside the tunnel. However, NILU has been commissioned to monitor air quality in the Ekeberg tunnel to assess the practical effect of ESPs on air quality. The results are expected to be available in 2002.

Hell Tunnel

The Hell Tunnel is 3.9 kilometres long and opened in 1995. It is a single tube with two-way traffic.

ESPs are installed in three ceiling locations, with one kilometre between each. The ESPs operated in the morning and evening peaks over two winters to overcome a major visibility problem in the tunnel because of studded tyres. The ESPs treated 25-30 per cent of air in the tunnel, with a practical affect on overall tunnel air of 15 per cent.

The ESPs have not been used for a number of years. The NPRA in Trondheim is currently using magnesium chloride laid on the tunnel surface to combat the particle problem from studded tyres.

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Nygard Tunnel, Bergen

The Nygard Tunnel is 900 metres long and opened in 1999. It has two one-way traffic tubes.

The NPRA officially recommended against the installation of ESPs, but municipality and county planning approval required installation in one tunnel tube pending investigations regarding the second tube.

The ESPs are in a state of operational readiness, but their use has not been required because of low particle levels.

Laerdal Tunnel, Laerdal-Aurland

The Laerdal Tunnel, the world's longest road tunnel, is 24.5 kilometres long. It is a single tube with two-way traffic. It is the most recently opened tunnel with ESPs.

The tunnel involves both a ventilation shaft and ESPs combined with nitrogen dioxide extraction equipment. The NPRA decided to install the ESPs and nitrogen dioxide equipment to treat air in the tunnel to improve visibility and for economic reasons.

Neither the ESPs nor nitrogen dioxide equipment has been used. Air quality standards are being met by use of the ventilation shaft.

Stromsas Tunnel, Drammen

The Stromsas Tunnel, a 3.7 kilometre single tube with two-way traffic, is scheduled to open in October 2001.

The tunnel includes ESPs in four ceiling locations, with 700 metres between each. The ESPs are a new generation of equipment, in part involving changes based on the lessons from the shortcomings of the ESPs in the Hell Tunnel.

The ESPs are expected to treat 70 per cent of tunnel air. The operating pattern of the ESPs has not been finalised, but they are expected to be triggered automatically by equipment measuring carbon monoxide levels. A timer switch for operation on a peak traffic basis will be used as an alternative.

NORWEGIAN ROAD TUNNELS WITH ESPs

Tunnel	Location	Length (m)	Open	Daily vehicles	ESP	Status
Festning	Oslo	1800	1990	60,000	Stack	Not operating
Granfoss	Oslo	2300	1992	15,000	Bypass	Not operating
Ekeberg	Oslo	1400	1994	45,000	Bypass	Business day traffic peaks
Hell	Trondheim	3900	1995	10,000	Ceiling	Not operating
Nygard	Bergen	900	1999	28,000	Ceiling	Operational but use not required
Laerdal	Laerdal	24500	2000	1,000	Ceiling	Operational but use not required
Stromsas	Drammen	3700	Oct 2001	est 12,500	Ceiling	
Bragernes	Drammen	2700	2002		Stack	

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Norwegian road tunnels without ESPs

Most rural road tunnels do not have ESPs. Six urban tunnels of about a kilometre in length or longer – all in Oslo – also do not have ESPs. These include two recently completed tunnels: the Tasen and Svardtal tunnels, which opened in 1999 and 2000 respectively.

NILU recommended against the installation of ESPs in the Tasen and Svardtal tunnels. The Svardtal Tunnel is an extension of the Ekeberg Tunnel and the Tasen Tunnel runs through a residential area of Oslo. Both tunnels have portal emissions.

Tunnel	Length (m)	Opened
Valerenga	830	1989
Nordby	3800	1993
Raelings	1820	1998
Follo	910	1998
Tasen	1350	1999
Svardtal	1360	2000

Assessment and monitoring of ESPs

ESPs have produced promising results in short-term tests under optimal conditions. Measurements immediately before and after ESP plates have shown a reduction in particles of 80-95 per cent. While these tests produce an operational guarantee standard for the ESPs, they do not show a practical filtration effect in road tunnels or outcomes over a medium to longer term.

Rigorous operational assessments of ESPs in tunnels have been conducted for the NPRA by SINTEF, a leading Norwegian research institute. The studies have shown:

- The particle extraction rate of ESPs decreases as air speed increases (see attachment).
- In the Hell Tunnel, although the particle extraction rate across the ESP is approximately as estimated by the equipment supplier, the practical improvement in visibility in the tunnel is not as high as expected.
- In the Hell Tunnel, ongoing break-downs of power packs in operational situations have provided problems.
- For some ESPs, the wash and dry cycle (12-20 hours for drying) has been complex and time consuming.
- In the Hell Tunnel, the bi-directional nature of the tunnel has involved problems with air flow around ESPs, including leakage, recirculation of air and piston effects from traffic.
- Good lessons have been learned to be incorporated in new generations of ESPs.

Air cleaning in road tunnels is a complex area that is still being developed. It remains an area of ongoing research and investigation for the NPRA. This work includes additional air quality monitoring in conjunction with existing tunnels, as well as new tunnels.

International interest and comparisons

Significant international interest has been shown in the work in Norway treatment of tunnel air.

It is important that conclusions about the use of ESPs in Norway are not simplistic generalisations. Tunnels, including any air treatment, are designed on a case-by-case basis. As reflected by the Tasen and Svardtal tunnels, it is not the case that ESPs are automatically installed

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in all new urban road tunnels. Additionally, installation does not necessarily mean current use. As outlined above, ESPs are currently operating in only one Norwegian tunnel.
Other countries should be cautious about applying a Norwegian tunnel solution in a Norwegian context to their own road tunnels. For example:

- The use of studded tyres in winter in Norway typically produces 70-75 per cent mineral particles in the air, a situation that does not exist with only conventional tyres.
- The past and current use of ESPs in Norway on a seasonal and/or peak traffic period basis does not relate to full-time ESP use. No ESPs have operated in Norway for 24 hours a day or treated 100 per cent of tunnel air.
- ESPs in Norway have operated in conjunction with emissions of air at tunnel portals. In some countries, this could result in breaches of air quality standards.
- Air quality standards can vary between countries: eg the Norwegian limit for carbon monoxide inside tunnels is 200 parts per million averaged over 15 minutes; the limit in tunnels in Sydney is 87 parts per million.

Future cooperation between RTA and NPRA

Despite the climatic differences and distance between Norway and Australia, there are similarities between the roads systems of the two countries. Both countries must provide roads through sparsely populated areas to link remote communities.

The Norwegian company behind the development of automatic tolling in Norway, Q Free, has also been central to the introduction of electronic tolling in Sydney.

The RTA acknowledges the expertise of the NPRA in tunnel construction and operation. It also acknowledges its ongoing efforts to improve the operation of ESPs.

The RTA and the NPRA agree to form an ongoing relationship to exchange information and experience on matters of mutual interest, including ventilation of road tunnels.

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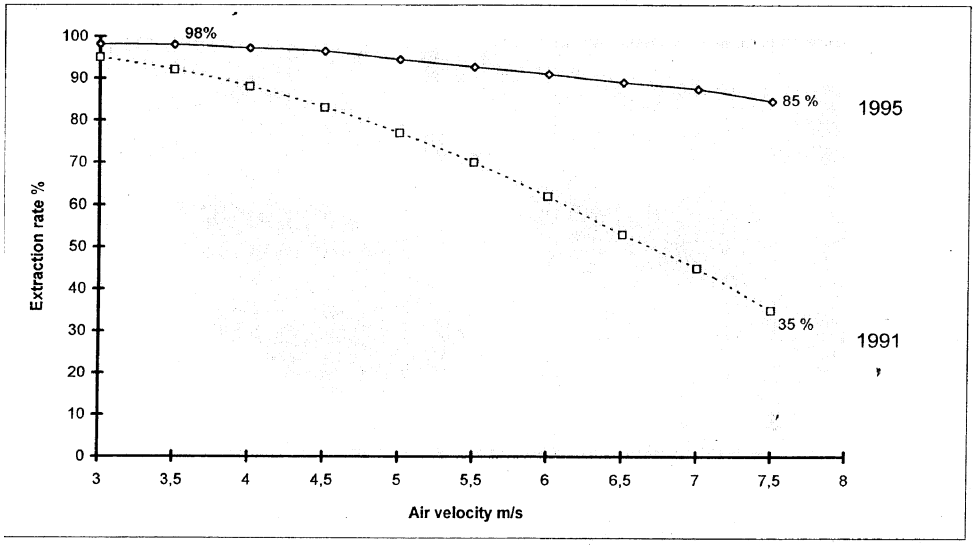
Extraction rate for electrostatic filters
Particle size 0,3 - 5,0 um



Average curve based on following standards : SAE , DOS , Atmospheric Air
Test carried out by SINTEF INSTITUTE, 1995

Public Roads Administration, Norway