Smoking tunnels

Dr Fathi Tarada, Managing Director of Mosen, raises the question 'Is smoke ventilation required for tunnels under construction?' in the light of recent dangerous incidents

Twin ducting arrangement for typical tunnel construction ventilation

In the wake of the Pike River colliery disaster in New Zealand, where 29 miners lost their lives, it may be time to reassess the issue of ventilation of tunnels under construction as well as mines. It is widely regarded that the Pike River disaster was caused by a methane build-up beyond the lower explosive limit of 4.4 per cent by volume. A total of four explosions resulted, with coal dust thrown up by the first explosion being involved in the subsequent explosions.

The fireball created by the initial explosion may have generated temperatures in excess of 1200°C, creating untenable conditions for human survival.

It is not just mines that are vulnerable to explosions and fires; tunnels under construction can also suffer from such events, causing great danger to human lives, and causing costly delays to construction programmes. A recent example is the diesel compressor fire in Canada's 10.4km long Niagara River Diversion Tunnel Project, which occurred on 27 April 2010.

Some 30 tunnellers working for contractor Strabag were forced to take refuge inside two emergency containers installed on the 14.4m-diameter Robbins Main Beam TBM, and four tunnellers were taken to hospital as a precautionary measure. The workers implemented the agreed emergency procedures, including attempting to extinguishing the fire. However, there was a large volume of smoke in the tunnel that needed to be dispersed.

Another recent fire in a tunnel under construction occurred in March 2010 at the 2.5km Vega del Ciego Tunnel that will form part of the high-speed rail line between Madrid and the Asturias region. The construction joint venture of Isolux-Corsan & Comsa (ICC) claimed that a spark in a sheet of waterproofing membrane caused the fire that then burned the tunnel's lining. The fire burned for nearly six hours, with more than 30 firefighters, mine rescue workers, ambulance workers and police involved in the control of the blaze. Five injured workers were treated for smoke inhalation and were all discharged the same day. Firefighters entered the tunnel from the southern portal and found the fire and heavy smoke about 500m from the portal. Fire chief Jaime Martin said that his men could hardly see through the smoke and that breathing apparatus was necessary at all times.

In the UK, a serious fire occurred in the Channel Tunnel Rail Link's (CTRL) Thames Tunnel on 16 August 2005. Two construction workers were killed in a fire that broke out in a diesel locomotive drawing a construction train south through the 2.5km-long, 8.15m-od eastern bore of the tunnel. Emergency services were called to the scene after a CTRL manager noticed smoke pouring out of the southern portal. Firefighters were able to extinguish the blaze with dry powder extinguishers before any major damage had been caused to the tunnel lining.

Fortunately the Saccardo ventilators for the permanent ventilation of the tunnel had already been installed, and this proved very useful in clearing the smoke from the tunnels. The fans at the Essex (north) portal of the bore where the locomotive was burning were actuated to blow the hot smoke away from the wagons containing large drums of cable, hence significantly reducing the potential fire spread. At the same time, the ventilators at both ends of the other tunnel bore were switched on. These pressurised the tunnel and cross passages to keep it clear of smoke. Tenable conditions for firefighters were therefore maintained throughout the fire incident.

Mechanical ventilation may be provided to tunnels under construction for a variety of reasons. It may be necessary to provide such ventilation to ensure an adequate air quality and temperature in the tunnels. Air quality is normally related to the dilution of pollutants (e.g. diesel smoke), the maintenance of adequate oxygen levels and the limitation of airborne dust (for visibility and breathability). Both air quality and temperature requirements for tunnel construction are reasonably well understood and catered for in the design of ventilation systems for tunnel construction. This understanding does not necessarily extend to emergency cases, however.

As evidenced by the incidents in the Niagara River Diversion Tunnel, Vega del Ciego Tunnel, CTRL Thames Tunnel and others, fires can generate a significant volume of smoke, even with relatively low heat release rates that do not threaten the structural integrity of the tunnel linings. Since most fatalities in fires are due to the inhalation of smoke rather than injuries due

to heat and flames, it is important to protect tunnel workers against the effects of smoke. In operational tunnels, smoke control may be achieved by moving the air in the desired direction at a velocity greater than the 'critical velocity' for smoke control. However, such a strategy may be too onerous in tunnels under construction, because of the large volumetric fan capacities that it would imply, and because the required air routes and power supplies may not be available yet. Alternative strategies such as the provision of pressurised emergency containers or the supply of breathing apparatus to tunnel workers are more realistic during the evacuation stage of a fire within a tunnel construction site.

Fire service personnel are often hampered by thick smoke during fire-fighting and search/rescue operations. The absence of a robust means of clearing smoke from a tunnel can therefore be a significant drawback, and can lose precious life-saving time. A number of fire brigades around the world have now equipped themselves with mobile ventilators to clear smoke from tunnels and underground spaces. For example, the fire service in Frankfurt am Main, Germany has both truck-mounted and track-propelled ventilators (with and without spray nozzles) that can be employed within the Frankfurt's expanding metro system. Tests undertaken indicate that the mobile ventilators can generate up to 3 metres per second within the metro tunnels, sufficient to clear smoke and allow a safe access to the seat of a fire.

BS 6164:2001 'Code of practice for safety in tunnelling in the construction industry' proposes that a safe system of work should be developed via risk assessment process, which includes consideration of the risk of fires. However, the issue of smoke ventilation is not explicitly considered. Although this standard is currently under review, smoke ventilation is not within the remit of the BS 6164 committee, and is therefore unlikely to be covered in the updated version.

Another issue that is relevant to fires in tunnels under construction is the types of combustibles that may be temporarily stored within the tunnel, or may form part of the tunnel structure. BS 6164 currently refers to the BS 476 series of standards for fire resistance, but makes no mention of the reaction-to-fire standards that specify limits to the heat release, production of toxic gases and flame propagation due to a fire (as provided by the BS EN 60695 series on 'Fire Hazard Testing', for example). Such specifications could conceivably have helped to mitigate the Vega del Ciego Tunnel fire that ripped through a tunnel waterproofing membrane.

The provision of emergency ventilation is clearly dependent on the fire risks perceived by a contractor, and will be contingent upon the type of construction method (e.g. TBM, drill-and-blast) and the phase of the project (e.g. boring works, electrical/mechanical fit-out, commissioning). Should any ventilators may be considered necessary, e.g. for smoke clearance, it may be agreed that these be deployed by the fire brigade rather than the tunnelling contractor.

Above: **A typical portable ventilation fan that could be used to remove smoke, but by tunnel workers or firefighters?**

Although the provision of emergency ventilation is not specified by the relevant tunnelling standards, the number of recent tunnel fires and explosions as well as their resulting casualties should give us reason to reconsider. After all, the provision of a safe system of work is clearly beneficial to all stakeholders within the tunnelling industry – and ventilation has a key role to play in ensuring a safe working environment for tunnel workers.

Right: **The 'Big Becky' Robbins TBM on the Niagara HEP project carries refuges that aided worker escape from fire smoke**
Below: **Inside a tunnel worker refuge chamber to escape from smoke**