Solutions for expl

Graham Ellicott, Chief Executive, Association for Specialist Fire Protection (ASFP), describes some of the recent research carried out into tunnel fires and puts forward the case for passive fire protection as an efficient remedial measure

No doubt as a result of some dreadful tunnel fire disasters over recent years, the Deutsche Montan Technologie GmbH (DMT) investigated and reported on the safety of 25 road tunnels in 2000. Compared to normal roads and major trunk routes, the risk of accidents in road tunnels is minor. Why is this? Well, road tunnels are not affected in the main by weather and have good operational systems such as lighting, speed limits and few junctions. Despite this, even small accidents in tunnels can prove difficult for the emergency services to manage due, in the main, to restricted access. But it is not only road tunnels that can have problems. The Swiss Bundesamt für Verkehr looked at the safety of rail tunnels and found that 110 out of 689 had safety problems. Thus, even though the incidence of accidents may be low in tunnels, any fire may prove difficult to control and this can lead to catastrophic consequences.

In recent years there have been several tunnel fires that have led to significant numbers of fatalities. The roll count includes the Baku Subway in 1995; 289 dead, the Mont Blanc tunnel in 1999; 39 dead, the Tauern tunnel in 1999; 12 dead and the Kaprun tunnel in 2000; 155 dead.

As we know, tunnels are constructed using either precast concrete sections sunk into a trench and covered, or by lining bored tunnels with concrete. There is a general perception that concrete will not burn and therefore must be fireproof. After all, at one time we used concrete to protect steel from fire, so it must be so! In a fire situation, however, concrete can suffer explosive spalling, showering pieces of concrete on to the tunnel's occupants, be they the trapped public of fire fighting service personnel. This spalling is caused by the residual moisture in the concrete boiling and causing high pressure steam, which in trying to escape will cause the concrete to crack and shatter, in some cases with explosive consequences.

The problem has been found particularly in high strength concrete and as long ago as 1976 the American National Institute for Standards and Testing (NIST) initiated research into the fire performance of the material. In the Channel tunnel fire in November 1996, the firemen complained that they were showered with concrete, and photographs of the railcars show their roofs sagging under the weight of the spalled material.

The NIST indicate that explosive spalling can be expected at temperatures between 300ºC and 450ºC and it is interesting to consider that steel sections, when fully loaded, lose their strength at between 550ºC and 600ºC but do not in fact start to lose strength quite as quickly. Work on bored tunnels using concrete linings in Holland shows that explosive spalling can occur within 10-15 minutes at surface temperatures of as low as 200ºC. It is proposed to limit surface heat to 200/250ºC in such structures. The Dutch experience claims that where the moisture content is over 3% of the mass, the risk of explosive spalling is 100%.

Protecting the 'worst case' scenario

After much research at the TNO laboratories and on existing structures, the Rijkwaterstraat (The Dutch Transport Ministry) takes the view that tunnels must be protected from fire in the 'worst case' scenario. Fire tests are required on an individual project basis and the tests are done to the special heating regime known as the RWS Curve (figure 1). This is more severe than the hydrocarbon curve used in the petrochemical industry as is shown on the graphs and has a maximum temperature of 1350ºC maintained for up to 2 hours.

Under the standard rules, the Dutch authorities require the surface temperature of the test piece to be restricted to 350ºC and the temperature at 25mm cover depth to 250ºC, which ties in quite well with the NIST experience. The imposition of this temperature limit leads to a requirement for added fire protective insulation to the concrete lining and tests of prospective materials must show no loss of bond, failure of fixing or explosive spalling during the test.

In order to protect tunnels from the ravages of high intensity fires, holistic solutions combining active measures (such as fire detection systems), management systems (such as evacuation procedures) and passive fire protection systems should be employed, after a detailed risk assessment has been carried out as part of the tunnel's design process.

Passive approach

In particular, passive fire protection systems are commonly used to protect the concrete in a tunnel and these products are easy to install. In the event of a fire these materials can result in the quick re-opening of the tunnel as they are relatively quick to replace in comparison to the reinstatement of fire damaged concrete.

Typical systems include proprietary spray applied cementitious products and autoclaved calcium silicate boards utilising inert fillers. The mechanism for the protection of the concrete by cementitious and calcium silicate products is twofold. Firstly, they contain trapped moisture, which in a fire situation will boil and keep the concrete temperature around 100ºC until all the water has disappeared. Secondly the product then acts as an insulator.

Below: Intermediate ceiling for ventilation, smoke extraction and cable ducts to ensure functioning. Western end of the Elbe Tunnel, Hamburg, Germany. Picture by kind permission of ASFP member - Promat UK Ltd

osive problems

But what are the specific benefits of these passive fire protection materials?

Firstly, the added extra insulation that they provide will eliminate repairs to the concrete following a fire, since the concrete temperatures will not have reached a high enough level. Temperatures as low as 160°C can mean that repairs will be needed. For example, concrete containing polypropylene fibres will need reinstatement as the additive will have melted. Once temperatures reach 300°C, the bond between the concrete and the rebar will have significantly reduced. At 380°C it is generally accepted that all concrete that has been exposed to these temperatures will need removal and subsequent repair. Even smouldering fires can dehydrate the surface of concrete and if a serious hydrocarbon then follows on, the level of explosive spalling is likely to be even greater.

Passive fire protection products do not impinge upon the long term durability of concrete as they have no affect on the porosity of the material, nor do they cause the formation of any cracks or channels that can admit harmful agents such as sulphates or chlorides that will attack the rebar.

Similarly, as proprietary passive fire protection products are placed between the concrete and the fire they have no effect on the properties of the concrete during placement, or in its lifetime. In comparison, additives used to infer extra levels of fire protection to concrete, can result in materials with complex mix designs that are difficult to pump or pour and that give poorer pull out strengths for anchors.

Another major benefit of proprietary passive fire products is that they are specifically designed, factory manufactured, tested and assessed for their end use and can be installed by companies that are members of third party accreditation schemes. Such schemes are referenced in Approved Document B Fire Safety to the Building Regulations for England and Wales which says:-

‘Since the fire performance of a product, component or structure is dependent upon satisfactory site installation and maintenance, independent schemes of certification and registration of installers and maintenance firms of such will provide confidence in the appropriate standard of workmanship being provided.’

The use of third party accredited applicators will become even more important in 2005 when the Regulatory Reform (Fire Safety) Order (RRO) is likely to become law. The RRO places the onus of fire safety on the shoulders of the ‘Responsible Person’, who is either the employer (where there is one), the person in control of the premises/structure, the owner or any other person who to any extent exercises control over the premises/structure.

Getting responsible

Under the RRO, the Responsible Person will be required to ensure that an assessment of the risk of/from fire is undertaken for the place and activity. Identified hazards will be removed, or reduced, so far as is reasonable and special consideration will be given to the risks posed by the presence of dangerous chemicals or substances and the risks that these pose in case of fire. Special consideration will also be given to any group of persons who may be especially at risk in case of fire, whether due to their location or any other factor.

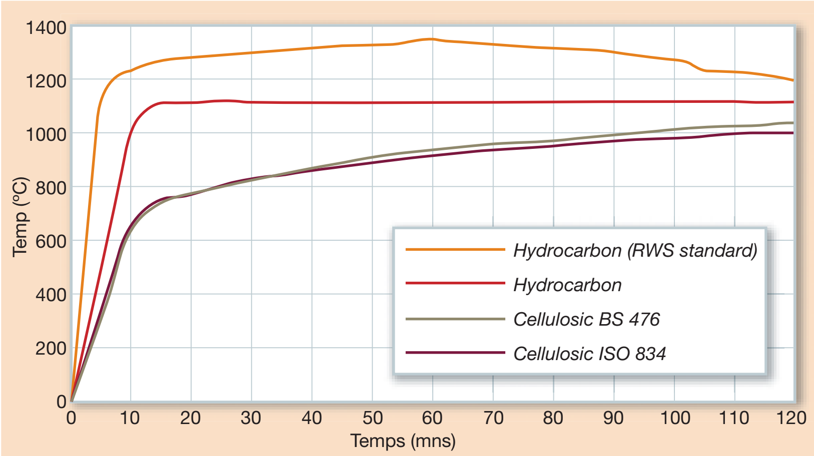
All precautions provided will be subject to maintenance and will be installed and maintained by a ‘competent person’. Under the RRO, a person is to be regarded as competent where he/she has sufficient training and experience, or knowledge and other qualities to enable him/her properly to assist in undertaking the preventive and protective measures.

Thus, where concrete needs extra fire protection, the use of proprietary passive fire protection products that are installed by third party accredited contractors using competent personnel, will allow the Responsible Person to demonstrate that he/she has taken reasonable measures to discharge their duties under the RRO.

Confident solution

In summary, the use of proprietary passive fire protection products to enhance the performance of concrete structures in fire will result in the faster re-opening of a fire damaged structure.

It will not affect the durability or the placement of the concrete and will allow those responsible for the fire safety of the structure to sleep more soundly at night.



Above: Fig 1 - the RWS curve graph

Below: Calcium silicate boards being fixed to a tunnel soffit. Picture by kind permission of ASFP member - Promat UK Ltd