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Fires in tunnels – can the risks be designed out?

The lorry fire that broke out on 26th July 2011 in the Brynglas Tunnel in South Wales caused severe traffic disruption for four days, and this has underscored the potential damage associated with tunnel fires. Could better design reduce the risks? The World Road Association (PIARC) will shortly be publishing a new report on design fires for tunnels, which will go some way towards clarifying how the tunnel fire risks can be assessed and managed. In particular, the report provides updated information on fire heat release rates and the time-development of vehicle fires, based on experimental tests. However, for those seeking instant answers to design fires in tunnels, the report delivers some rather sobering conclusions: a universal design fire cannot be specified, because the probability and size of any fire is inherently unknown. The choice of design fire therefore needs to be made with some care – and there will always be a residual risk that a real fire will be greater than the design fire.

The new PIARC report limits itself to considering design fires for the sizing of equipment in tunnels (e.g. ventilation) and the development of scenarios when developing emergency

response plans. The report therefore does not consider structural fire protection issues, which are left to other standard-setting bodies such as the International Tunnelling Association. The key

parameter used in the report to describe fire size is the heat release rate, typically measured in megawatts (MW).

The fire sizes adopted in different countries is presented in the PIARC report. The comparison indicates that several countries adopt different fire sizes depending on the type of vehicle admitted to a tunnel, recognising the risk of larger fires with heavy goods vehicles and dangerous goods. It is also clear that countries that only utilise longitudinal ventilation allow for higher design fires, since this mode of ventilation can generally be designed to deal with larger fires at reasonable expense, while the same consideration with transverse ventilation systems (e.g. in Alpine tunnels) would require a significant increase in the costs of tunnel structure and equipment.

In its previous report on design fires published in 1999, PIARC recommended a tunnel design fire size of 30 MW. However, that report acknowledged that significantly higher heat release rates from heavy goods vehicles and vehicles with dangerous goods are possible based on the experimental measurements undertaken during the EUREKA fire tests. These indicated peak fire heat release rates of up to 120 MW. The heat release rates from fires arising from petrol tanker fuel spills were considered to depend on the leakage rate and drainage, in the range of 200 to 300 MW.

In the meantime, a number of experimental test programmes were undertaken with fires in tunnels, which seemed to indicate that very high fire heat release rates are possible, even with conventional goods. These included a series of fire tests at the disused 1,600m-long Runehamar tunnel in Norway, funded by the EU's UPTUN project. The Runehamar tests showed that heat release rates of between 66 MW to 202 MW are possible due to fires in heavy goods vehicles loaded with a combination of wood pallets (80% of mass) and plastic (20% of mass). Recognition of these experimental results has been made by a number of standard-setting bodies, including the National Fire Protection Association, whose latest 2011 edition of the NFPA 502 code recommends a range of 70 to 200 MW for the peak fire heat release rates from heavy goods vehicles.

While recognising that high heat release rates are indeed possible due to fires in heavy good vehicles, the new PIARC report counsels caution in applying the UPTUN experimental data directly for design purposes. It points out that the experimental design of the Runehamar tunnel itself may have promoted large fire sizes. For example, the combustible load was covered with tarpaulin, which burnt away readily, and hence allowed an unimpeded flow of oxygen into the fire. In order to protect the Runehamar tunnel structure, an 'inner tunnel' comprising fire protection boards had been built. Because of this, the combustible load was close to tunnel walls and ceiling, which promoted radiative heating, and also meant that high ceiling temperatures were measured. Based on considerations of all the fire



Figure 1 Runehamar Fire Test Loads

tests undertaken to date, **Table 1** on page 49 presents typical peak fire heat release rates for different road vehicles.

Another issue highlighted by the PIARC report is the effect of air velocity on heat release rates. Although the control of smoke movement in a tunnel through the application of a longitudinal airflow is generally recommended, particularly for unidirectional tunnels, it is acknowledged



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that increasing air velocities may have the effect of enhancing the heat release rates of open fires. This is because more oxygen is transported to the fuel, increasing the combustion rate, and the deflection of the flame increases fire spread and consequently the fire growth rate. However, fires in enclosed vehicles are less sensitive to tunnel air velocities.

In the event of a major tunnel fire, the ultimate responsibility for rescuing motorists and extinguishing the fire almost invariably falls on the fire brigade. Fire fighters themselves need to be protected from the effects of smoke and heat radiation, and tunnel safety-related equipment should therefore be designed to provide such protection, as far as possible. However, the Runehamar and other fire tests have shown that heat radiation in fires over 50-100 MW may be too high for the fire brigade to approach and extinguish the fire. Such limitations need to be considered in setting the design fire size for tunnel equipment.

While the required fire heat release rate for tunnel equipment design is prescribed in some countries' standards, other countries allow for at least a certain amount of flexibility in the design approach for fire protection. Such a 'performance-based' approach allows alternative solutions to fire protection to be considered, which may allow design and construction costs to be reduced. For example, a reduction in the design fire heat release rates from 200 MW to 100 MW was agreed for the Alaskan Way Viaduct Tunnel in Seattle and the San Francisco Presidio Parkway Tunnels, on the basis that fixed fire suppression systems are installed. This allowed a reduction in the required duct sizes and fan capacities for smoke control, which more than offset the fire suppression installation costs.

The new PIARC report does not specifically address issues relating to fire suppression, although it does recognise that a range of measures can be deployed to reduce the risk of fire down to acceptable levels. These can include the use of fixed fire fighting systems, improved fire detection, improved response methods, operational measures such as the prohibition of certain dangerous goods, and better traffic management. The report also accepts that a case can be made for reducing the fire heat release rate down from prescriptive values, on the basis that a fixed fire suppression system would cool down any fires.

The effect of fire suppression in tunnels has





Images of the SOLIT2 fire tests

Table 1 Typical Peak Fire Heat Release Rates for Different Road Vehicles

Vehicle Type	Peak Fire Heat Release Rate [MW]
Passenger car	5 – 10
Light duty vehicle	15
Coach, bus	20
Lorry, heavy-goods vehicle up to 25 tonnes	30 – 50
Heavy-goods vehicle, typically 25-50 tonnes	70 – 150
Petrol tanker	200 – 300

been considered by a number of experimental tests, including the UPTUN project. These have confirmed the potential beneficial effects of water in reducing temperatures and slowing the rate of fire spread, attenuating heat radiation, protecting tunnel assets, and in allowing safe evacuation and fire-fighting operations.

hence downstream oxygen concentrations would be depleted.

While a universal design fire size for tunnels cannot be defined, there is a wealth of information available in the new PIARC report that allows designers, authorities, tunnel owners and operators to make an informed choice



However, there are a number of potential drawbacks, including reductions in visibility, spread of spilt hydrocarbons, and explosive interactions with certain dangerous goods.

The on-going SOLIT2 research project, currently underway at the TST facility in Spain, should provide some answers to on-going design issues related to tunnel fire suppression. I recently returned from attending fire tests at that facility, where I had an opportunity to walk right up to a large burning fire load which had the potential of generating 150 MW, had it not been suppressed by water mist down to about 25 MW. A key finding from this personal experience is that the numerical value of heat release rate is of little consequence in the case of fire controlled by a suppression system. The majority of heat from the fire is absorbed in converting water to steam, rather than in emitting harmful radiation or producing excessive air temperatures. It is still the case however that oxygen is consumed by the fire,

regarding the most appropriate value for their tunnels. That should be part of a process of risk analysis and assessment, the outcome of which is a design which fulfils the required safety level in a tunnel, to the benefit of motorists and society at large.



Dr. Fathi Tarada is a leading expert in fire safety engineering, tunnel ventilation and Computational Fluid Dynamics, with design, review and operations experience in tunnels and buildings worldwide. Fathi is also Founder & Managing Director of Mosen Ltd. He is the inventor of the MoJet® tunnel ventilation system, and has submitted a dozen patent applications in the field of mechanical engineering. Fathi is the Co-Chairman of the World Road Association (PIARC) Working Group on Air Quality, Fire and Ventilation, the Chairman-Elect of BHR's International Symposium on Aerodynamics and Ventilation of Tunnels, and the chairman of the Fire Protection and Safety in Tunnels Conference.