Smart Transportation Alliance

The role of concrete pavement in tunnel safety

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1. Introduction

The social role of transportation infrastructures is undeniable. They service citizens by connecting people with hospitals, schools and workplaces. For this very reason, transportation infrastructures –particularly roads in the context of this Technical Report-, must be not only efficient, but also safe.

Tunnels represent one of the features of the road network where safety concerns become more important. Road tunnels hold unique characteristics and deserve special attention, even if accidents do not occur more often in tunnels than in other points of the road network.

However, any serious incident involving them causes great social alarm, given 1) the actual difficulties posed to rescue or evacuation interventions, 2) the drama caused to drivers due to the closed configuration of a tunnel and 3) the serious disruption which may involve the temporary closure of a road, mainly when there are difficult or non-existent alternatives to detour traffic.

Some recent fires in tunnels across the world have stressed the need to adopt efficient measures in order to minimize risks for both people and the infrastructure itself, as shown in Table 1. In this context, materials and computer simulation become essential tools to develop innovative safety solutions to improve safety conditions in road tunnels.

Place of accident	Tunnel type Length	Year	Duration Temperature	Casualties	Damaged vehicles
Fréjus France–Italy	Road (1 tube) 12.9 km	2005	6 hrs 1200° C	2 deaths	9 cars
St Gotthard Switzerland	Road (1 tube) 16.3 km	2001	24 hrs 1200° C	11 deaths 35 intoxicated	10 cars 13 lorries
Gleinalm Austria	Road (1 tube) 8.3 km	2001	37 minutes	5 deaths	2 cars
Tauern Austria	Road (1 tube) 6.4 km	1999	14 hrs 1200° C	12 deaths	24 cars 16 lorries
Mont-Blanc France-Italy	Road (1 tube) 11.6 km	1999	53 hrs 1000° C	39 deaths	32 cars 2 lorries
Palermo Italy	Road	1999	–	5 deaths	19 cars 1 coach

Table 1 – Summary of recent fires in European road tunnels
Source: Author's own elaboration

2. Pavement behaviour in case of fire

Due to the high risk of fire, it is mandatory to ensure that all materials used during the construction stage of a tunnel provide the highest safety level. In this sense, the pavement of the carriageway represents an important part of the cross section in a road tunnel.

The presence of combustible materials in the pavement can result into significant distress in case of fire, as they would contribute to increasing the fire load, emitting toxic fumes and destroying the structural properties of the referred element, therefore making evacuation operations more difficult.

Nonetheless, the main risk involved in the presence of a combustible material in pavements is the change induced in fire dynamics. It must be noted that, when a temperature of 485ºC is reached, asphalt burns. Despite the fact that asphalt combustion generates a low amount of heat, the truth is that such heat is produced in the lower part of the vehicle, changing fire dynamics and speeding it up. This heat generation in the lower part of the tunnel makes the fire widespread and causes a sudden and dramatic increase of power – see Figure 1.

Speeding up the fire brings then a significant increase of smoke, in addition to the fumes generated by the combustion of the pavement. As a result of this, once the pavement starts burning, conditions around the fire will worsen quickly, preventing firemen from working under safety conditions.

In case the power exceeds 50 MW, fire could also spread to other vehicles. This effect may trap firemen between two fires, since intervention teams have to be as close as 20 meters from the original fire, so as to put it out and new fires can be set behind them. Avoiding this sudden increase of power caused by the combustion of asphalt pavements is essential to guarantee the safety of fire fighters.

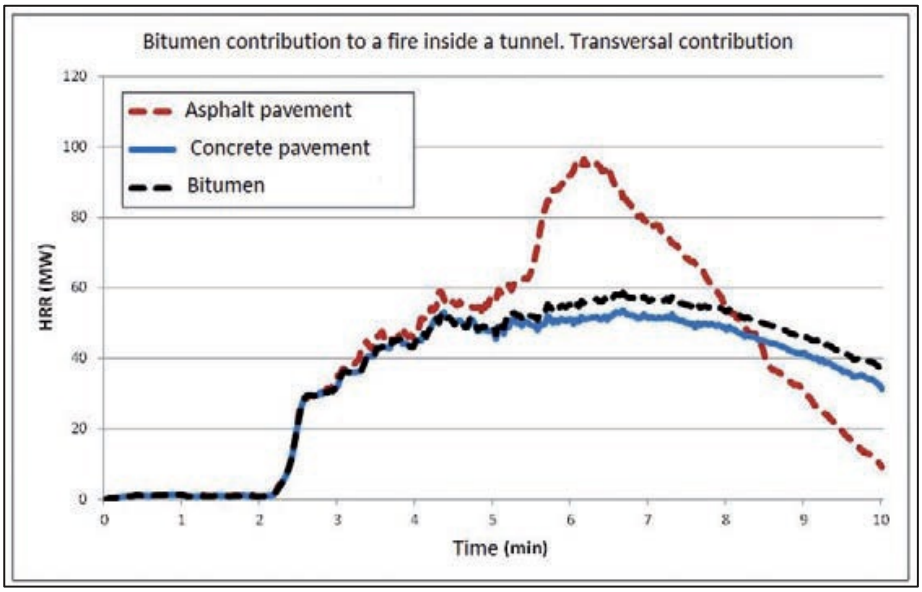

Figure 1 – Sudden increase of power due to a change in the fire dynamics
Source: Author´s own elaboration

Last but not least, this combustion in the lower part of the tunnel may cause the explosion of the wheels of heavy vehicles, an additional risk to firemen who are next to the fire. In addition, since asphalt is a thermoplastic material whose viscosity decreases with temperature, it becomes significantly softer at temperatures ranging between 150ºC and 180ºC, which are reached approximately 5 minutes after the beginning of the fire and at a distance of 45 meters from the origin of the fire.

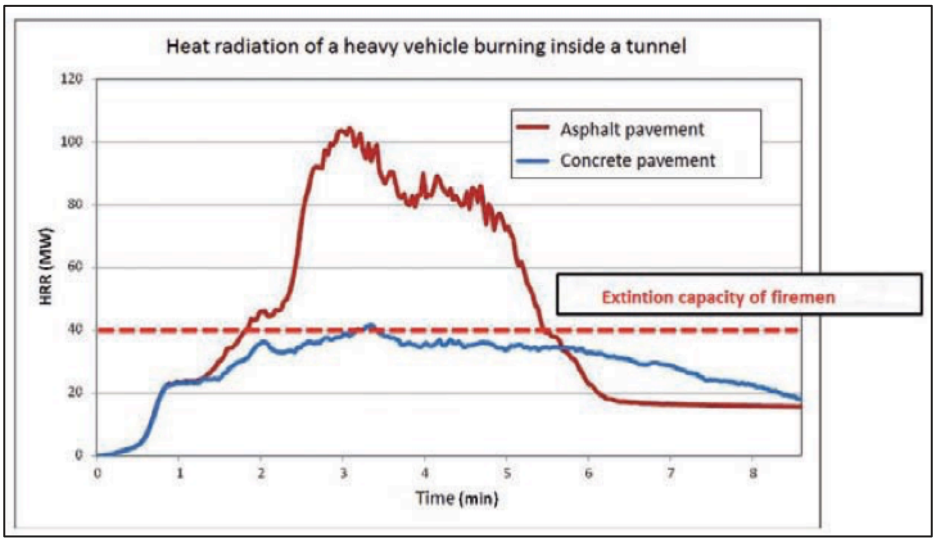

Figure 2 – Power of fire for different scenarios
Source: Author´s own elaboration

This distance is longer than the working distance of firemen and it makes their mobility inside the tunnel more complicated. If asphalt contribution to fire were limited to the energy generated by burning pavement, the power increment would be 4 MW, since the burning surface considered is 100 m2 and the unit power emission is 40 kW/m². This power would represent the 8% of total energy fire and it should not significantly worsen working conditions. However, the fact is that fire dynamics are often changing and emission rates drastically increase after the asphalt starts burning.

Figure 3 shows the difference between both types of combustion processes, depending on the type of pavement. Concrete pavements (non-flammable), thanks to their inert behaviour, act as heat accumulators, and their stability under high temperatures allow intervention teams to access the tunnel.

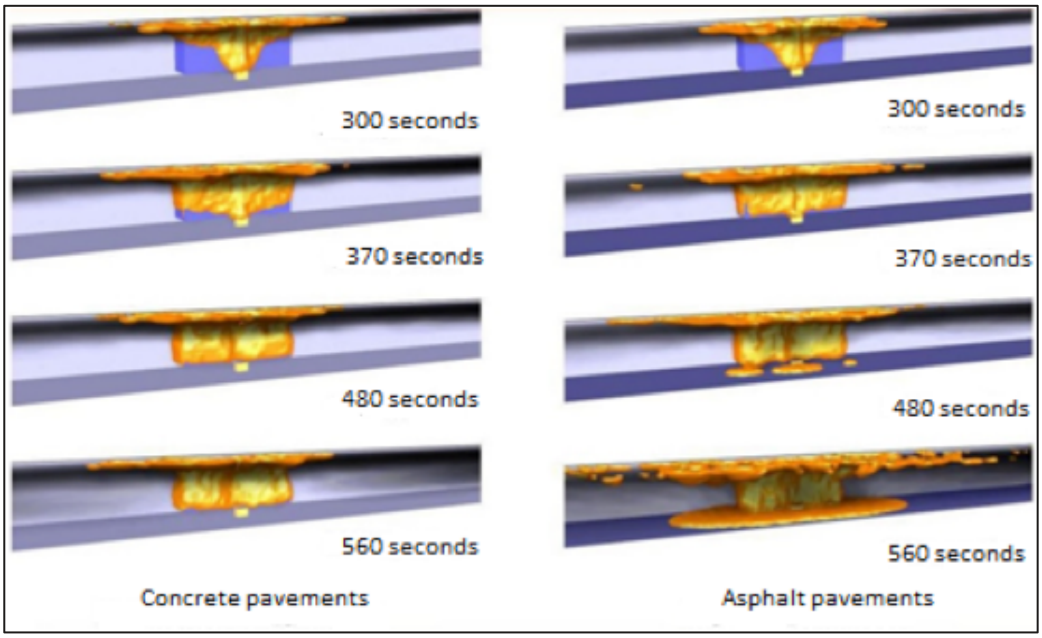

Figure 3 – Differences in fire progress for different scenarios
Source: Author´s own elaboration

3. Conclusions

This author believes that the rules regulating in some European countries the use of concrete pavements in tunnels whose length is over 500m (Austria) or 1000m (Spain) are therefore well-founded. The amount of fumes and heat released by burning asphalt surfaces is comparable to that produced by the combustion of a truck. The heat energy that asphalt surfaces may release, generated in the low part of the tunnel, can change the dynamics of the fire, leading to an increase of its intensity. Consequently, the fire could easily spread to other vehicles through the pavement. Additionally, the increase in firepower could mean that the design load of ventilation systems was exceeded, making the fire harder to fight and resulting in a higher risk for people and for the structure.

This unfortunate effect took place in some fires that occurred inside tunnels at the end of the 1990s in Austria, France and Italy, and they all resulted into tragedies. When fume extractors are insufficient to eliminate fire gases, heat accumulates inside the tunnel causing other vehicles to catch fire and larger asphalt surfaces to burn. The author's proposal is that any element that contributes to make the situation worse should be eliminated or minimised.

In some particular cases, the use of concrete pavements may be the key factor that allows keeping the amount of heat and gases below the standard design limits, so that the extraction system keeps working until the situation is under control.

4. Bibliography

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