Passive fire protection and life safety

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Abstract: The structural integrity and resilience of tunnel linings are enhanced with passive fire protection systems, using boards or spray mortar. When assessing the performance of these systems, fully developed fires are assumed, and the passive fire protection prevents the load bearing structure to prematurely loose strength and stiffness during the fire incident, as well as mitigates structural damage, including severe cracking in case of concrete tunnel linings. As such passive fire protection contributes to life safety, allowing evacuees to safely egress the hostile environment, and emergency response teams to safely intervene, but it also provides inspection, investigation and repair workers a reliable working environment. However, passive fire protection also contributes to life safety in earlier stage of fire development. Research reveals that passive fire protection systems using boards or spray mortars may indeed contribute to tenability, by providing higher probability of stratification, over longer distances and for longer time periods, allowing evacuees more opportunities and time to safely find there way to (emergency) exits. This paper presents results from advanced studies, using sophisticated (CFD) computer simulations. In particular, fire scenarios involving a car and a HGV truck have been studied, with varying (longitudinal) ventilation conditions. The influence on life safety conditions is discussed in terms of temperature, visibility and the radiation level, all as a function of the distance from the fire, with a view to assess the risk to evacuees and fire spread (ignition of other vehicles).

Keywords: passive fire protection, ventilation, tenability, life safety

1 Introduction

Tunnels are a vital and vulnerable point of the transportation networks global wide. In case of an accident and closure of the tunnel, for instance for repair work due to losses of durability or structural loadbearing capacity, the socio-economical impact would be rather enormous.

The structural integrity and resilience of tunnel linings during and after a fire are enhanced with passive fire protection systems, using boards or spray mortar. When assessing the performance of these systems, fully developed fires are assumed, and the passive fire protection prevents the load bearing structure to prematurely loose strength and stiffness during the fire incident, as well as mitigates structural damage, including severe cracking in case of concrete tunnel linings. As such passive fire protection contributes to life safety, allowing evacuees to safely egress the hostile environment, and emergency response teams to safely intervene, but it also provides inspection, investigation and repair workers a reliable working environment.

In this paper, it is studied in which way the use of passive fire protection in tunnel linings can also contribute to life safety conditions at the beginning of a fire. This positive hypothesis is based upon observations of the BENELUX fire tests, where a tunnel provided by passive fire protection at the ceiling, shows the existence of a stratified smoke layer over a very long distance. It was expected that this stratification would not stand that long due to cooling down of the hot air. It is clear that from a life safety point of view, the existence of such a stratified smoke layer has important advantages.

In this paper, the effect of passive fire protection to life safety conditions is studied by means of FDS for a 200 m long tunnel with a 6 MW car and 200 MW HGV truck fire near the tunnel, under varying longitudinal ventilation rates (0-3 m/s).

2 Results of the 6 MW car fire

Generally, no significant differences can be found between protected and unprotected tunnels for life safety conditions in terms of temperature, visibility and radiation.

3 Results of the 200 MW truck fire

3.1 Gas temperature at 1.5m height

The study indicates that for the situation of 3 m/s ventilation, tenability criteria with respect to maximum temperature (e.g. < 60°C) are exceeded in the tunnel, for both protected and unprotected situation. Also in case of no ventilation (0 m/s), the temperatures are mostly still too high for the unprotected tunnel. On the other hand, for the case of 0 m/s, the protected tunnel shows the best tenability conditions with respect to temperature. Table 1 summarizes the distances in the tunnel at which different tenability limit criteria are met.

Table 1. Distance in the tunnel at which the tenability limit criteria are achieved for the case of 0m/s ventilation

	< 60°C	< 120°C	< 190°C
Protected (PFP200MW0ms)	120 m	70 m	45 m
Unprotected (CON200MW0ms)	195 m	175 m	150 m

From this study, the positive contribution of passive fire protection on improved tenability conditions is clear, resulting in additional evacuation distances compared to the unprotected tunnel of 75 m for the limit of < 60°C, 105 m for < 120°C and 105 m for < 190°C (see Table 1). This positive contribution must be attributed to a higher ceiling temperature as heat loss through the protected ceiling and walls is less, resulting in a stratified smoke layer for a longer distance and expected time.

3.2 Visibility

The visibility at 1.5 m height towards light emitting and light reflecting signs is studied. A life safety criterion of 10 m is used. It was found that when ventilation is turned on (study case of 3 m/s), the criterion is not met inside the tunnel for both the protected and unprotected situations. Mutual differences between both situations is also not significant.

Also in case there is no forced ventilation (0 m/s), the results showed the difficulty to achieve the limit criterion. However, it was found that the use of passive fire protection enhances the visibility extremely. For the protected tunnel the criterion is obtained at 153 and 157 m, respectively for visibility towards light emitting and light reflecting signs. On the other hand, for the unprotected tunnel, the criterion is only reached near the tunnel exit, respectively at 195 and 198 m. Hence, for 0 m/s, the study confirms the positive contribution of passive fire protection on life safety in tunnels.

3.3 Radiation

In the full paper, a discussion is given regarding the results about received radiative heat flux with respect to life safety and fire spread.

4 Conclusions

Conclusions should state concisely the most important propositions of the paper as well as the author's views of the practical implications of the results.

A clear difference is found between 6 MW and 200 MW fire. In view of the study, it is interesting to evaluate also an intermediate scenario, such as a bus fire of 30 MW.

The use of forced ventilation (study case of 3 m/s) dramatically influences the tenability conditions and the fire spread risk downstream of the fire, for both passive fire protected and unprotected tunnels.

When no ventilation is used, the passive fire protected tunnel has much better life safety possibilities in terms of temperature and visibility, whereas for radiation no significant difference is found. This positive effect is explained by a stratified smoke layer over a longer distance and time for the protected tunnel, induced by a higher temperature of the hot smoke layer. Toxicity is not studied.

Given above conclusions, forced ventilation could be only an option if downstream evacuation is not a problem. Downstream traffic jams can be a problem.

A detailed analysis of the risk for fire spread to other vehicles is out of the scope of this paper. Further research should focus on time-dependent calculating (of the material properties and the fire) and modeling of the actual burning process (instead of an imposed HRR-curve).

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