

Characterization of the ignition and burning behaviour of and the fire spread across asphalt.

1. Introduction

The size of a fire and thus its hazard potential is substantially controlled by the flame spread. How much a fire spreads is again mainly influenced by the surface temperature at ignition (T_{ig}), the thermal properties of the material tested, in particular the thermal inertia ($k_s \rho_s C_s$), the heat release rate, the flame spread property Φ and the minimum heat flux for spread.

Due to the fire incidents in road tunnels during the last decades, the possibility of asphalt pavements being an additional fire risk in tunnels has recently received increasing attention.

2. Material and Methodology

Asphalt consists basically of an aggregate skeleton and a binder (bitumen). Figure 1 shows a sample of the tested asphalt.

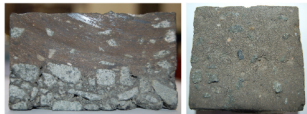


Figure 1: Asphalt sample tested consisting of surface course (upper part) and binder course (lower part)

The ignition and burning behaviour was determined using the Cone Calorimeter and the FM Global Fire Propagation Apparatus (FPA) respectively. The flame spread was assessed by means of the radiant panel test.

3. Observations

After the test, the surface texture was very crumbly and bumpy. The very top of the surface course was covered with a minute layer of dust. Furthermore, the surface colour changed from black to light brown. Figure 2 pictures two samples after burning.

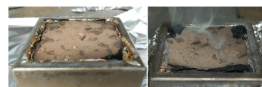


Figure 2: Asphalt samples after Cone Calorimeter test

The rocks in the binder course are no longer connected to each other by the bitumen at an external heat flux of 50 kW/m² (Figure 3).

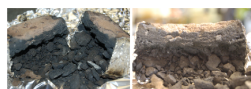


Figure 3: Rocks in the binder course are no longer connected to each other by bitumen after Cone Calorimeter test.

5. Conclusion

Further investigations with regard to asphalt as additional hazard potential in tunnel fires needs to be done for particular cases. The tested asphalt within this study does not provide much of an additional risk, as no flame spread was observed for an external heat flux of 28 kW/m². The critical heat flux at extinguishment was determined to be around 19.8 to 22.5 kW/m².

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4. Results

Ignition Temperature (T_{ig})

The ignition temperature was roughly estimated with thermocouples and calculated using the following equation.

$$T_{ig} = T_0 + \frac{\dot{q}_{0,ig}^*}{h_r}$$

Cone Calorimeter:

T_{ig} measured: 422 and 442 °C, respectively.

T_{ig} calculated for $h_r = 45 - 55 \text{ W/m}^2\text{K}$ and a critical heat flux of 21-21.8 kW/m²: 403-519 °C

FM Global Fire Propagation Apparatus:

T_{ig} calculated for $h_r = 45 - 55 \text{ W/m}^2\text{K}$ and a critical heat flux of 26-30 kW/m²: 493-697 °C

Thermal Inertia

The thermal inertia was calculated from the heat transfer equations, thus the temperatures within the sample determined from thermocouple experiments. Furthermore it was calculated from the following equation:

$$\bar{k}_s \bar{\rho}_s \bar{C}_s = 4\pi \left(\frac{1}{\sqrt{t_{ig}}} \right)^2 \frac{(T_{ig} - T_0)^2}{\dot{q}_c^2}$$

Cone Calorimeter:

Thermal inertia heat transfer equations: 2.31 (kW/(m²K))²s

Thermal inertia for $T_{ig} = 350-475 \text{ °C}$ and external heat fluxes of 40-60 kW/m²: 1.11-2.6 (kW/(m²K))²s

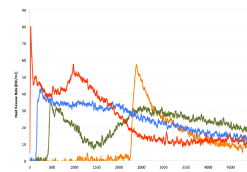
FM Global Fire Propagation Apparatus:

Thermal inertia for $T_{ig} = 400-675 \text{ °C}$ and external heat fluxes of 40 and 50 kW/m²: 1.85-5.99 (kW/(m²K))²s

Heat Release Rate

Cone Calorimeter:

Heat release rate curves have different shapes for varying tests.



Tables 1 and 2 show some heat release rate data.

Specimen	External Heat Flux [kW/m ²]	\dot{Q}_{max} [kW/m ²]	Time to peak [s]	\dot{Q}_{ave} [kW/m ²]	\dot{Q}_{ext} [kW/m ²]
CC CHP	21.8	37.56	2390	40.86	43.61
CC 25 I	25	41.7	972	4.89	80.72
CC 25 II	25	38.66	1330	5.78	9.30
CC 25 III	25	26.63	1050	6.76	14.90
CC 30	30	37.00	500	24.97	26.96
CC 40 I	40	45.07	268	34.75	35.54
CC 40 II	40	45	168	39.07	37.84
CC 50 I	50	63.97	113	50.97	48.45
CC 60	60	66.48	65	76.58	53.13
CC 75	75	79.89	23	53.01	48.99

Specimen	Test duration [s]	Total heat release rate $Q_{t, tot}$ [MJ/m ²]	Total mass loss [kg/m ²]	Effective heat of combustion ΔH_{eff} [MJ/kg]
CC CHP	2793.5	50.408	4.14	14.45
CC 25 I	2750	26.910	2.70	8.87
CC 25 II	2750	21.949	2.29	8.45
CC 25 III	4827	117.491	6.22	18.85
CC 30	7869	137.215	6.33	21.01
CC 40 I	6511	136.013	6.80	20.001
CC 40 II	2680	85.194	5.05	16.87
CC 50 I	5023	167.157	7.56	21.958
CC 60	6000	171.708	7.71	22.16
CC 75	4963	124.777	8.17	15.71

Tables 1 and 2: Peak heat release rates, time to peak heat release rates, average heat release rates after 180 and 300 seconds, total heat release rates, total mass loss rates, calculated effective heat of combustions.