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May 2013

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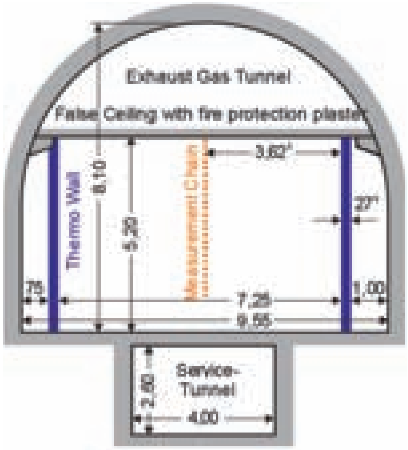
mineARC SYSTEMS

Testing times for water-mist systems

Under the SOLIT 2 research project, more than 30 major tests were carried out on water-mist fire-suppression systems for use in road tunnels. Roland Leucker explains

Figure 1a: San Pedro de Anes test tunnel, Spain; Figure 1b: cross-section of the same test tunnel



THE German research project Safety of Life in Tunnels 2 (SOLIT 2) was started in 2009 with the aim of investigating the interaction in road tunnels between water-mist fire-suppression systems and other safety installations, such as fire ventilation.

As installing a fire-suppression system incurs additional costs, the aim at the outset was to avoid increasing costs for the entire safety installations in the tunnel. Instead, the idea was to examine how other measures could be compensated for by means of a holistic approach.

The project, which ran until 2012, was sponsored by the Federal Ministry for Economics and Technology as a result of a decision of the German Bundestag.

The findings obtained within the scope of more than 30 major fire tests on a 1:1 scale in May and June 2011 in a test tunnel in Spain (Fig. 1a) were of central importance to the project. To this end, half the tests were carried out as pool fires featuring fire loads of between 30MW and 100MW; the other half were solid-matter fires with complete lorry-loads comprising 100MW substitute fire loads of wooden pallets.

EXECUTING THE FIRE TESTS

Test-tunnel geometry

The test tunnel has a total length of 600m and is slightly S-shaped. It has a longitudinal incline of 2‰ and in its rough state has a horseshoe cross-section (9.55m wide and 8.10m high) characteristic of road tunnels (Fig. 1b).

In order to protect the tunnel's concrete structure from excessively high temperatures in the fire zone, walls had to be erected at the sides, restricting the test cross-section to a width of 7.25m. The test zone's height was restricted to 5.2m, thanks to an intermediate false ceiling protected by plaster fire protection.

The space above the intermediate ceiling was used as an exhaust duct for the semi-transverse ventilation. Behind the new side walls, there was room to install extensive measuring and recording equipment. The middle of the fire load in the tunnel's longitudinal direction was defined as 0.00 for all distance specifications (Fig. 2).

Water-mist fire suppression system

To carry out the tests, a water-mist fire-suppression system was temporarily installed in the test zone over a distance of 60m. Two rows of nozzles were attached to the false ceiling in a longitudinal direction. The system's water supply came from diesel-driven pumps, which were set up in a container outside the tunnel. The pumps operated at full capacity 30 seconds after being switched on.

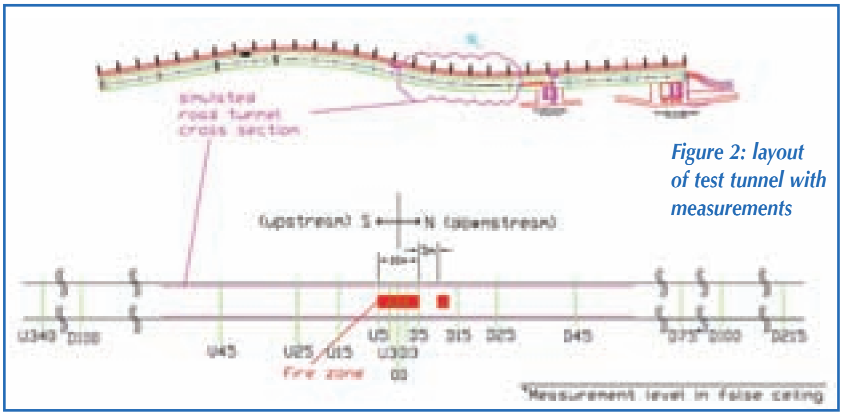


Figure 2: layout of test tunnel with measurements

Ventilation

The tunnel is fitted with a longitudinal and semi-transverse ventilation system. Longitudinal currents of 1-6m/sec can be achieved with jet fans attached to the ceiling. The optional semi-transverse ventilation expels up to 120m³/sec via a ventilation station at the northern end of the tunnel above the intermediate ceiling (air speed of up to 30m/s). Fourteen ventilation flaps are installed in the ceiling between the tunnel and the exhaust duct – each with a gross cross-sectional area of 1.5m². The semi-transverse ventilation is dimensioned for fires releasing up to around 30MW of heat.

Solid-matter fires (truck fire)

The test set-up for a solid-matter fire (100MW) in each case consisted of 408 standard Euro wooden pallets. This corresponds to a weight of some 9t with a total energy content of 110-140GJ. The fire load was roughly 10m long, 2.4m wide and 2.5m high, thus resembling a →

truck-load. In the tunnel's longitudinal direction, it was set up symmetrically to the zero point.

Some of the solid-matter tests were undertaken on a platform around 1.5m high, roughly corresponding to the height of a truck's loading area. The total height with fire load of 4m corresponds to the height of a loaded truck.

For most of the solid-matter tests (11 out of 15), the pallets were covered with a PVC tarpaulin. On the one hand, this reflected a realistic situation in road traffic during which a fire occurs on the loading area beneath the tarpaulin. On the other hand, it represented unfavourable conditions for the water-mist fire-suppression system because the fire is protected from the mist sprayed from above for a lengthy period.

In order to discover whether a fire flashover occurs between two vehicles, a stack of pallets was set up ('target') at a distance of 5m downstream – in other words, in the direction of flow behind the fire load. This stack of pallets was the same height and width as the fire load.

Measurement system

During a fire test, the relevant parameters were registered every two seconds with 152 sensors in the tunnel. Depending on the test duration, up to around 350,000 measurement values were recorded per test, including temperature, heat radiation, air speed, gas concentration (O_2, CO_2 and CO), pressure and flow rate of the fire-suppression system, and air humidity.

Test set-up

For solid-matter fires, the water-mist system was generally activated after four minutes. It was presumed that two minutes elapse between a fire breaking out until the time it is detected; and a further two minutes until the water-mist system is completely activated. The fire duration and in turn the period during which the fire could develop freely – influenced only by the water-mist system – amounted to some 30 minutes. The fire was then extinguished by the fire service. Only then was the water-mist system switched off and the processing of the measurement data completed.

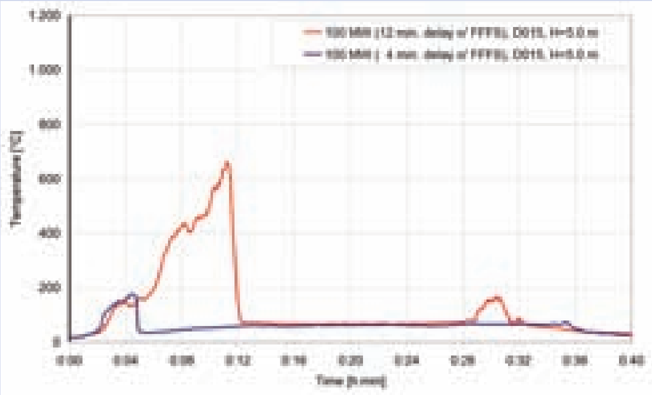


Figure 3: temperature curve under the false ceiling 10m behind the fire load

Evaluation of the fire tests undertaken

In the following, the way the water-mist system works is explained by taking the examples of two solid-matter fires. An example is provided in the form of a fire with the customary delay in activating the water-mist system (four minutes after igniting the fire load) compared with delayed activation of the systems (12 minutes after ignition).

As with all solid-matter tests undertaken, the scheduled heat-release rate amounted to 100MW. The height of the fire load was 4m (including the 1.5m-high platform).

Longitudinal ventilation was set at roughly 3m/s flow speed for both tests. For the fire involving the four-minute delay in activating the water-mist system, the semi-transverse ventilation was additionally activated: 120m³/s of fire gases were expelled via the smoke exhaust duct above the tunnel. The water-mist system's nozzles were positioned 5m above the carriageway.

The positive effect of the water-mist system in the cross-section 10m behind the fire load (15m behind the middle of the fire load – D015, Fig. 3) can be recognised as clear and representative.

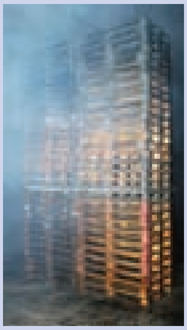


Figure 4: 'target' undamaged after fire test with 12-minute delay in activating water-mist system

After four minutes, the temperature in the upper zone (at a height of 5m, in other words 0.2m beneath the false ceiling) rises to 150-175 °C. After activating the water-mist system (in the test with a four-minute ignition time) the temperature drops to roughly 60°C. In the test with an extended ignition period (12 minutes), the temperature first increases unchanged, but by the time the water-mist system is activated, reaches about 650°C. After the system is activated, this drops rapidly to reach roughly 65 °C.

In addition to the measurement values obtained, the target (a second stack of pallets) set up 5m away from the fire load also displays the effect of the water-mist system in suppressing the fire.

After both the four-minute ignition delay fire and the 12-minute ignition delay fire, the target was unharmed (Fig. 4) – apart from a few traces of soot. However, the fire load had almost completely combusted – in the case of the four-minute ignition delay fire, 80% of the pallets had burned and the remainder had largely been charred; in the case of the 12-minute ignition delay fire, the pallets had completely burned.

SUMMARY AND OUTLOOK

Within the scope of the SOLIT 2 research project, more than 30 major fire tests were carried out in May and June 2011. Altogether, some 6,000 Euro pallets for solid-matter fires and around 8,000L of diesel for pool fires were burned.

The presented test results reveal that a water-mist system can positively influence the development of solid-matter fires, as well as pool fires. In both cases, the water mist has a cooling effect on the fire load and on the environment, so that temperatures increase less rapidly. This effect makes itself felt first and foremost a few metres behind the fire load (in the direction of flow). In this way, the danger of fire flashing over to other vehicles – as the targets showed – is reduced to a great extent. Furthermore, the lower temperatures around the fire make it possible for the fire service to tackle the blaze.

One noteworthy result of the project was that an 'Engineering guidance for a comprehensive evaluation of tunnels with fixed fire-fighting systems' was elaborated. This guidance provides a methodology to engineers to examine, evaluate and plan the component parts of a tunnel safety system. The focus is laid on the use of fixed fire-fighting systems (FFFS) and the interaction of these systems with other safety measures. The guidance and the corresponding documents can be downloaded from www.stuva.de.

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