IN THE SMOKE

Petr Pospisil of consultancy Tunnelventilation.pro gives this reflection on the realities of a fire in a tunnel, and the disorientating effects that can still be in effect despite ventilation

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IN 2003, I participated in smoke tests in a long road tunnel in Slovakia. Ten years later I remembered my personal experience and asked myself: Where are we now with safety and ventilation of road tunnels. The conclusions are in some aspects disillusioning.

The Branisko tunnel is a 5km long road tunnel with bidirectional traffic in Eastern Slovakia, which was opened in 2003. An escape tunnel is situated parallel to the road tunnel. The tunnel is equipped with a semitransversal ventilation system with smoke extraction dampers, which was designed in the 1990s. Having to inherit a tunnel ventilation concept which was not really adequate, particularly in controlling the longitudinal airflow, I contributed on the final design, and was responsible for the operation and control algorithms, the commissioning and acceptance tests of the tunnel ventilation system. Beside that, I worked out the concept, design and realisation of the escape tunnel ventilation system.

SMOKE EVENT

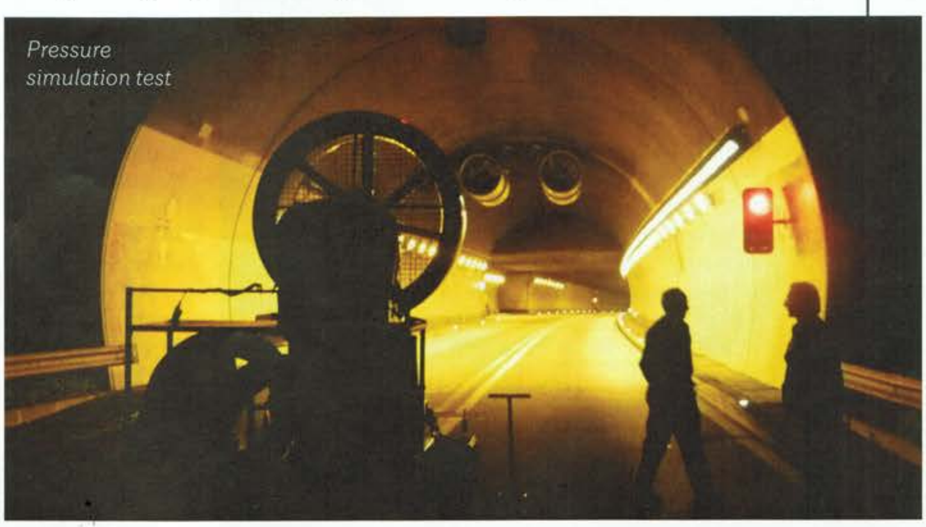
At the final acceptance test, smoke tests were carried out to demonstrate the effectiveness of the fire ventilation system. It has to be pointed out that before that all safety systems should have been successfully proven. To simulate tunnel fires, we proposed military smoke generators that were designed originally for the screening of tanks, producing a large amount of artificial smoke, with a heat release sufficient to enable a stratification. However, health aspects were not addressed. In fact, the test smoke was quite irritating to the respiratory system.

The first test was a success. Although the smoke extraction capacity was not sufficient, due to high duct leakages, the fire ventilation system was able to limit the spread of smoke and finally to remove the fumes from the tunnel. During the second smoke test, a breakdown of the power supply led to the failure of one of two exhaust fans, and additionally of one supply fan in the opposite tunnel section which was used to slow down the longitudinal airflow. As a consequence, the smoke spread over the whole length of the tunnel due to strong buoyancy forces. Later, the power supply could be fixed and the smoke finally removed from the tunnel.

I attended the smoke tests in the tunnel standing beside a cross passage to the escape tunnel, and left my car in a lay-by opposite to the cross passage. When the tunnel was filled with smoke due to the system failure, I decided to evacuate myself to the cross passage which was supplied with fresh air. The power supply of the escape tunnel ventilation was attached to the UPS according to my recommendation, enabling a high level of availability.

After a few minutes, I realised that my dog was trapped in the car, and that the smoke could affect his health. Therefore, I decided to save my dog und pick him up. The distance between the cross passage and the car was approximately 20 m. While walking in the tunnel, the visibility was nearly zero and I hold my breath to not respire the fumes. I found my car quickly, took out my panting dog, and tried to get back to the cross passage. However, it took longer than expected to reach the opposite tunnel wall, which was only a few meters away. When following the tunnel wall to the cross passage, I suddenly realised that I might be going to the wrong direction. Meanwhile, I could not longer hold my breath and had to respire, using my handkerchief as a filter. Following along the wall in the opposite direction, finally I reached the fresh air cushion which built up in front of the cross passage. That was an effect of the air streaming through the pressure relief damper, which was situated over the escape door. Happy, but coughing, my dog and I entered the safe space.

This experience was very informative for my further career as tunnel safety and ventilation designer and expert. It was a simulated emergency when I knew that my life was not threatened, where I had a good overview of the situation, knowing the positions of the lay-by and the cross passage. Nevertheless, I had problems finding my way through the smoke along a distance of only a few dozen meters. But after all, why did a system that cost Millions of EUR and was supposed to have been tested out,



Pressure simulation test

suddenly fail when it was needed?

WHERE ARE WE NOW?

A lot is written about risk analysis using theoretical personal escape models. National guidelines require escape way distances in the magnitude of hundreds of meters. My experience shows that persons may fail to reach escape ways in a tunnel filled with smoke and zero visibility even on short distances. Many car drivers don't notice the position of the escape doors, and most casualties of fire incidents die from smoke exposure.

Because short distances between escape ways are not economically feasible in most tunnels, the ability of the ventilation system to effectively control the spread of smoke is crucial. Particularly in highway tunnels with unidirectional traffic, with a longitudinal ventilation preventing smoke spread against the traffic direction, escape ways have little effect on the safety of tunnel users. However, the safety issue is more complicated in tunnels with bidirectional traffic or in unidirectional city tunnels, where congestions are supposed to happen and people may be trapped on both sides of the fire location.

Again, there are plenty of theoretical papers on tunnel ventilation issues, but in practice, for many ventilation systems we don't even know whether they will work unless an incident happens, because they are never tested thoroughly under realistic conditions. Particularly the testing of tunnel ventilation systems under random boundary conditions, without simulating the decisive driving forces like traffic, wind and buoyancy, is not really useful.

Most important of all, the complete system including power supply, control system, actuators and sensors must be taken into account, defining failure modes and safe operating states. A reliable power supply must have the highest priority. I had personally attended two smoke tests in tunnels in different countries, where the fire ventilation failed due to a breakdown oft the electric power supply (let it be understood: after all systems were supposed to have been tested out).

There are plenty of examples of system failures in practice, but of course the tunnel operators and responsible designers are not keen to publish them. In real incidents, those failures may cost human lives.

A positive aspect is the effectiveness of the escape tunnel ventilation, which keeps the safe zone free of smoke. The ventilation concept of the Branisko tunnel, with fans situated in airlocks at both ends of the tunnel, generating an overpressure in the whole escape tunnel and an airflow in open escape doors towards the traffic tunnel, was later adopted as a basis for the Swiss guideline for ventilation of escape tunnels (ASTRA 13002) and therefore is standard in many Swiss and other European tunnels. Moreover, the proposed design was in accordance with the later published European standard EN 12101-6.

Above: Scenario involving a moving smoke source

However, the escape tunnel ventilation must fit together with the escape door design. I know about many examples where people are not able to open the escape doors due to excessive pressure generated by the ventilation system, particularly when using flap doors.

Smoke tests took a step ahead. Today, we provide non toxic, non corrosive test smoke, which features many characteristics of real tunnel fires (optical density, layering effects). Most important of all, we simulate influencing boundary conditions for the longitudinal airflow in the tunnel (traffic, wind, buoyancy), thus being able to reproduce the design conditions as realistically as possible. Nevertheless, we still see smoke tests being worked out with pool fires or smoke generators producing toxic, corrosive smoke, in empty tunnels with random boundary conditions, which have nothing to do with a real incident under traffic, nor with the design conditions. And in many tunnels, no realistic smoke tests are performed at all.

CONCLUSIONS

My little adventure shows a lot about the effectiveness and reliability of fire ventilation in practice and reasonable distances of escape ways. However, the safety issues have to be addressed on a higher level.

Only short distances between escape ways are useful to safe people in a tunnel fire incident when the tunnel is full with smoke. Where such short distances are not practically feasible, the spread of smoke must be effectively controlled by the ventilation system.

Many tunnels are equipped with complicated ventilation systems, which are never thoroughly tested out and as a consequence often fail in practice. Instead of that, ventilation systems should be as simple as possible, but its reliable, proper function must be ensured under all circumstances. 'Proper function' does not mean that the fan impeller is turning, but that the spread of smoke in the tunnel is effectively controlled.

Authorities are advised to define clear goals for the ventilation system to achieve for defined design conditions. Operational requirements should ensure safe, reliable function of the complete ventilation system (including control system and power supply) considering possible failure of components. Most importantly of all, achievement of goals must be proven in detail for all possible scenarios, by acceptance tests of the whole system in a real tunnel as part of project quality management. What's not tested, will not work