Model tunnel

When assessing the safety of road tunnels it is necessary to look at the overall system as well as the interaction of individual components. The system encompasses the users of the tunnel, the tunnel structure, tunnel operation and vehicles.

Tunnel ventilation and its design constitute a major element of equipment, especially for self-rescue and successful evacuation in the case of fire. Due to the increasing complexity of road tunnels – and therefore also of the ventilation equipment – there is a need to further develop the previous method of specifying ventilation systems.

Fires in particular present a potential risk when using tunnels. Self-rescue is initially paramount during a fire, and this is supported by the technical equipment in the tunnel. Above all, correct use of the tunnel ventilation systems plays a crucial role here. The requirements for the ventilation system, maintenance and operation are set out in rules and standards.

Uniform safety standards are defined in these rules and standards to minimise the risk and the magnitude of the failure of a ventilation system. Since, however, every tunnel is unique because of its position and the prevailing circumstances, special solutions are required in exceptional cases.

The tunnel in the laboratory

Since 2016, the model tunnel at BASt has provided a tool with which even complex tunnel geometries can be simulated at a scale of 1:18 and can be examined with respect to ventilation issues.

The tunnel was developed, built and tested between 2012 and 2015 by RWTH Aachen University on behalf of BASf. The project was funded by the Federal Ministry of Transport.

The facility

Currently the model tunnel with a modular construction offers the opportunity to simulate tunnels with a length of up to 790 metres. The following parameters can be set:

- Route mapping and cross-section, including changes to the cross-section
- Longitudinal and transverse gradient
- Arrangement, position, size and speed of fans
- Breakdown bays, ceiling and side haunches, entrances and exits
- Traffic signs and other technical installations

The tunnel also permits the simulation of stationary and moving traffic, operating the tunnel either as a twin-tube or a single-tube tunnel. 40 vehicles, 25 percent of which are trucks, can travel around the circuit at the same time.

The tests

In addition to the classic measurement of flow conditions by recording pressure differences, the innovative Particle Image Velocimetry (PIV) measurement procedure is also available. With this method, tracer particles are introduced into the air flow in the tunnel using a mixture of helium and compressed air.

A powerful laser illuminates the section of the tunnel to be examined and makes it possible to record the particles using an ultra-sensitive camera. Then several computer programs calculate the flow conditions in the tunnel from these images.

Two-dimensional and three-dimensional images can be created. The three-dimensional view is obtained by positioning two cameras at a defined angle to each other, both recording events simultaneously. The stereoscopic effect of this method enables conclusions to be drawn about the spatial distribution of the flow.
Focus of further research

Further steps planned by BASt involve comparing the results from the model tunnel with large-scale fire tests and flow tests conducted in moving traffic with different tunnel geometries.

Through a combination of the model tunnel in conjunction with improved numerical simulation opportunities, the aim in the medium-term is to provide a tool that facilitates an objective and transparent determination of safety equipment from an economic, safety-related and structural point of view. This applies to the planning of new tunnel structures, and to the retrofitting of existing tunnels.

The expansion of the model tunnel to incorporate additional geometries, ventilation systems and route mapping elements is possible.

Technical data

Scale 1:18
Maximum structural length 44 m ≈ 792 m in reality
Fan sizes for mechanical longitudinal ventilation shown to scale: 500, 710, 900 mm
Fan speed up to 30 m/s
Longitudinal gradient 0 to 6 %
Transverse gradient 2.5 to 7 %
Arched and rectangular profile with 2 lanes (in accordance with the RQ 11 t and RQ 31 t)
Twin-tube or a single-tube operation
PIV measurement system as 2C (one camera) and 3C (two cameras)

The benefit

As well as basic examinations into flows, the model tunnel has also been designed for use as a tool to investigate special solutions and their economic optimisation.

Special solutions – which thus far have exclusively been numerically calculated – frequently only get close to reality to a limited degree. Because of these imponderables, the practical implementation of such solutions often results in the introduction of a higher safety factor than necessary, which in turn leads to avoidable higher costs.

A further advantage is the simulation of moving traffic in the model tunnel. The simulation gets closer to subsequent operating conditions than all tests that have previously been applied in tunnels and makes it possible to estimate traffic influences.

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