



ENGINEERING
EXCELLENCE



Tunnel ventilation

ILF
CONSULTING
ENGINEERS



Ventilation is a key element of electro-mechanical equipment and is crucial to the safety of tunnel operation. Due to increasing safety requirements, the ever-increasing length of tunnels and environmental protection issues, more and more demands are being made on tunnel ventilation systems today. At the same time, the design must focus on energy efficiency and tunnel availability. This applies to road, rail and metro tunnels alike.

All-in-one ventilation design

■ Tunnel ventilation know-how

The ventilation system greatly influences important parameters of the overall tunnel design. The earlier the aerodynamic concept and emergency response to fire are taken into account, the greater the efficiency and cost effectiveness with which these requirements can be harmonised with those of construction design, safety engineering and all other electro-mechanical equipment.

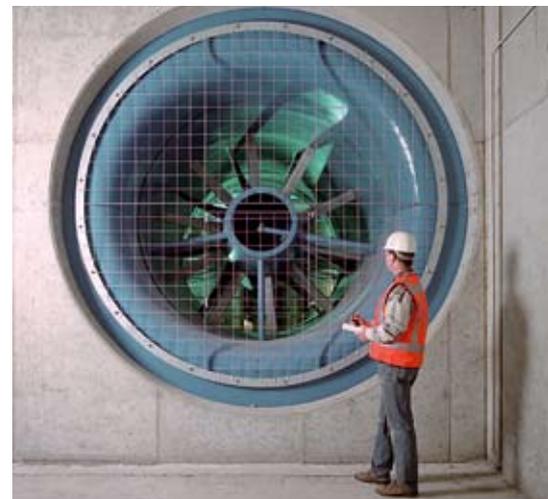
ILF has dealt with the holistic and interdisciplinary design of tunnels including ventilation systems for more than three decades. The company has successfully designed and supported the implementation of extremely complex ventilation systems all

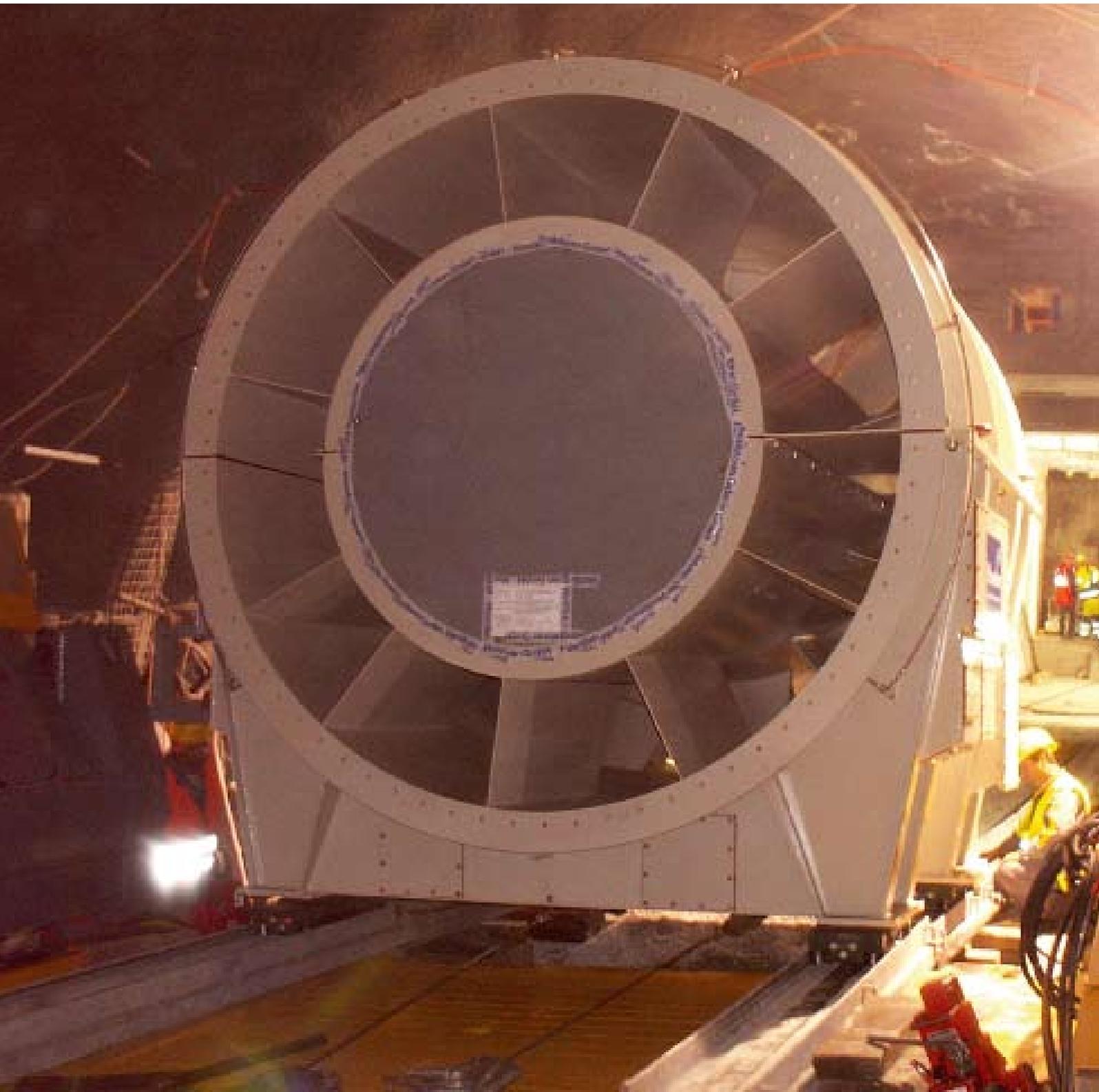
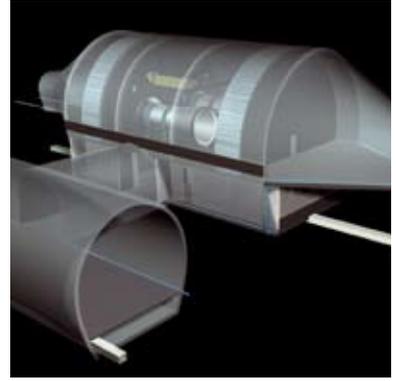
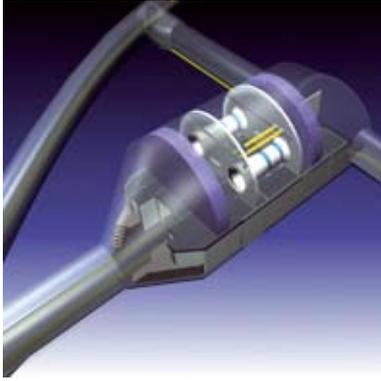
- the longest bidirectional tunnel in Germany (Kramer - design stage)
- the longest tunnel in the Provincia Autonoma di Bolzano, Italy (currently the tunnel in San Giacomo but soon that in Laives)
- equipment for the longest Alpine base tunnel at the time of its completion (Lötschberg)
- design of the ventilation system for the longest rail tunnel in Austria to date (Wienerwaldtunnel)

ILF has also been entrusted with safety studies for the Swissmetro project, with retrofitting the Arlberg rail tunnel with safety equipment (approx. 10.6 km/6.6 miles), with the addition of a second bore to the Bosruck road tunnel (5.5 km/3.4 miles) and with the design of many complex ventilation systems.

over the world and has played a leading role in the field of ventilation technology in the following superlative projects:

- the longest bidirectional tunnel in Austria (Arlberg)
- the bidirectional tunnel with the greatest volume of traffic in Austria (Pfänder)
- the longest road tunnel in Germany (Rennsteig)
- the longest unidirectional tunnel in Switzerland - client support (Seelisberg)







■ Special insights

In addition, ILF designs the complex ventilation systems that are required for the construction of tunnels and the installation of equipment. These ventilation systems play a crucial role in ensuring that long construction and equipment installation projects are completed efficiently and according to plan. Good ventilation design can have a decisive impact on running costs, the performance of workers, site availability and safety on an ever-changing branched site. An intelligent solution that is tailored to the construction schedule and that brings together all stages of design can win the contract.

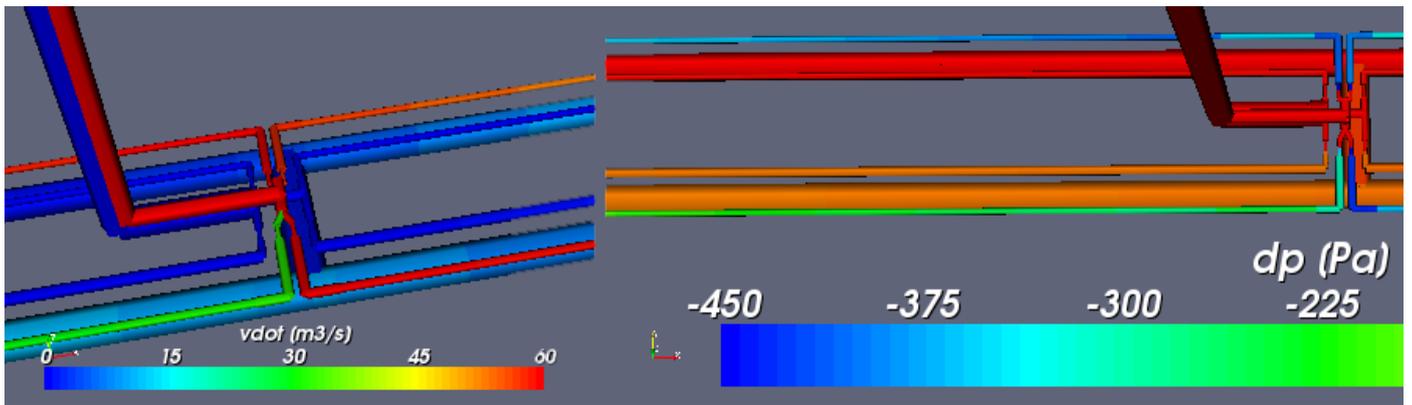
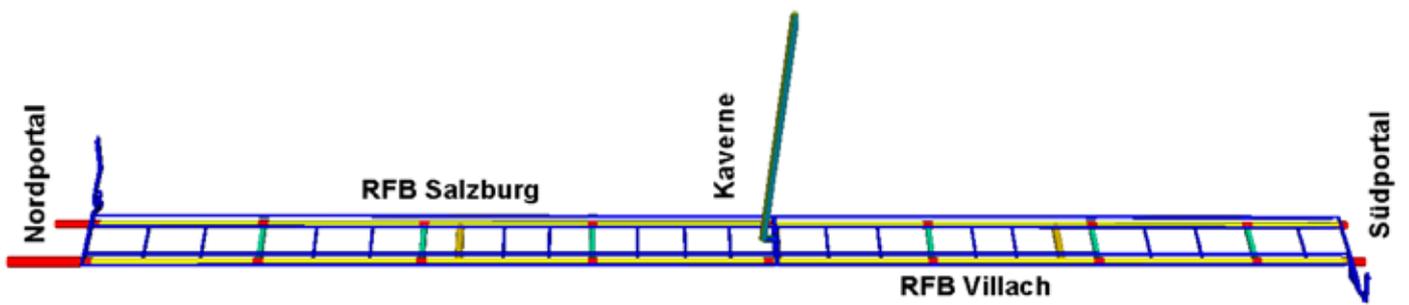
In this context, it is also important to point out that the harmonisation of cooling and ventilation systems is decisive for energy efficiency and construction logistics. In connection with alpine tunnels with high overburden and tunnel building sites with very high waste heat, ILF has, for example, developed and successfully implemented a special system which uses very little energy to dramatically reduce the cooling systems required. In some cases, cooling systems can even be dispensed with.

On the basis of profound specialist knowledge in the fields of thermodynamics and fluid dynamics and armed with comprehensive practical experience, ILF's ventilation experts support clients with state-of-the-art software and hardware, the latest measuring equipment, sound expertise and a wealth of on-the-job experience.

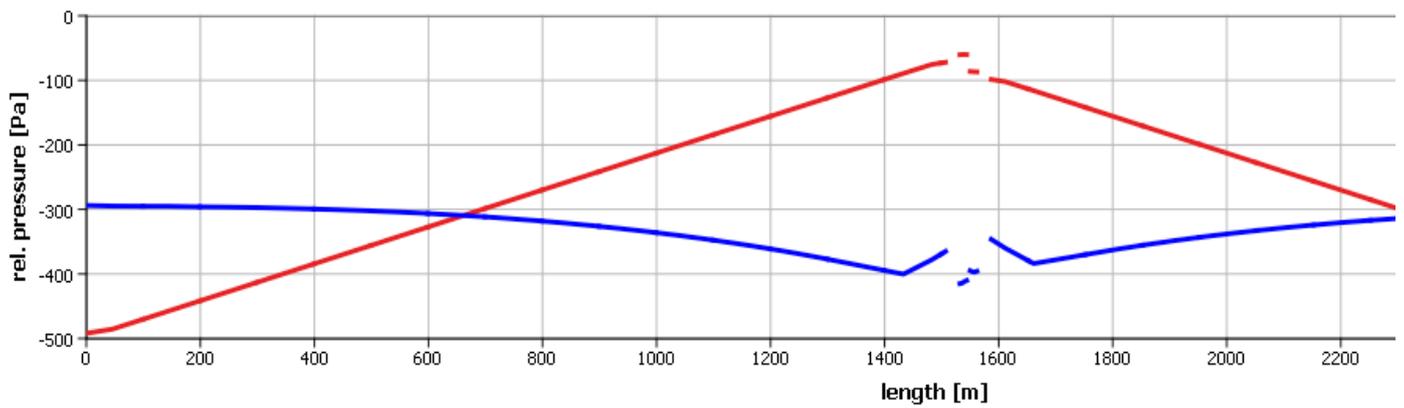
Thanks to design work on an international scale, the development of its own software and participation in specialist conferences and relevant working groups, ILF is a leading ventilation designer on the global stage today. It goes without saying that ILF is well familiar with all the details of the regulations and standards that are applicable in countries all over the world.

■ Comprehensive design

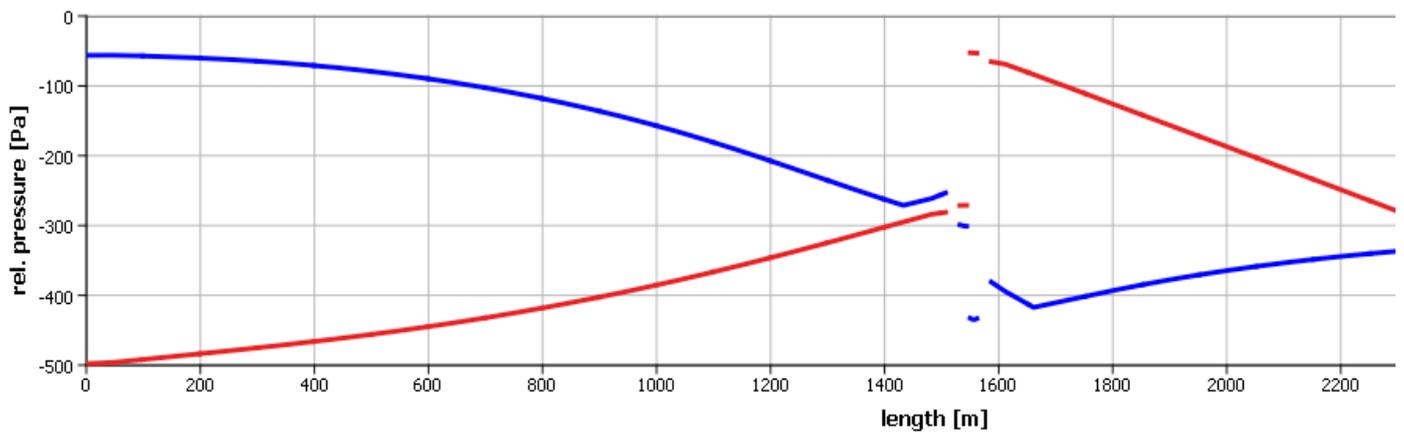
ILF's experts have proven their worth in various capacities and in various stages of complex ventilation projects all over the world. ILF is therefore in a position to provide expert support for the construction of new and the rehabilitation of old road and rail tunnels from design through to execution and commissioning. One of ILF's special strength is that its ventilation experts can continuously confer with specialists from supporting fields such as tunnel construction, tunnel safety, electro engineering, structural engineering and architecture.



TAS 3.1 und TAS 2.1



TAV 3.1 und TAV 2.1



Simulation of tunnel ventilation

■ Tunnel systems

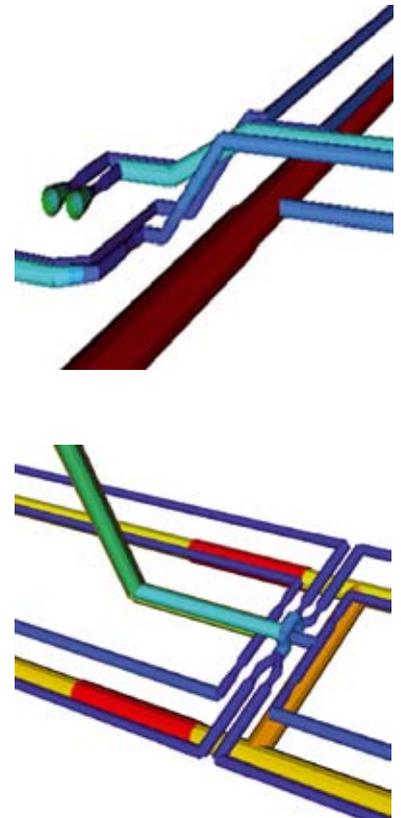
ILF uses NUMSTA (Numerical Simulation of Tunnel Aerodynamics) software for the transient simulation of air flow in complex tunnel systems. In contrast to the numerical procedures used to date (which are all based on the characteristics method), NUMSTA is based on the transient form of Euler equations which are discretised using 2nd-order solvers in a Finite Volume (FV) method. The source terms for mass transfer, momentum transfer and energy transfer can be superimposed to achieve more realistic simulation results. This method has been assessed in the course of the scientific development and has also undergone comprehensive validation through comparison with data gained from real projects.

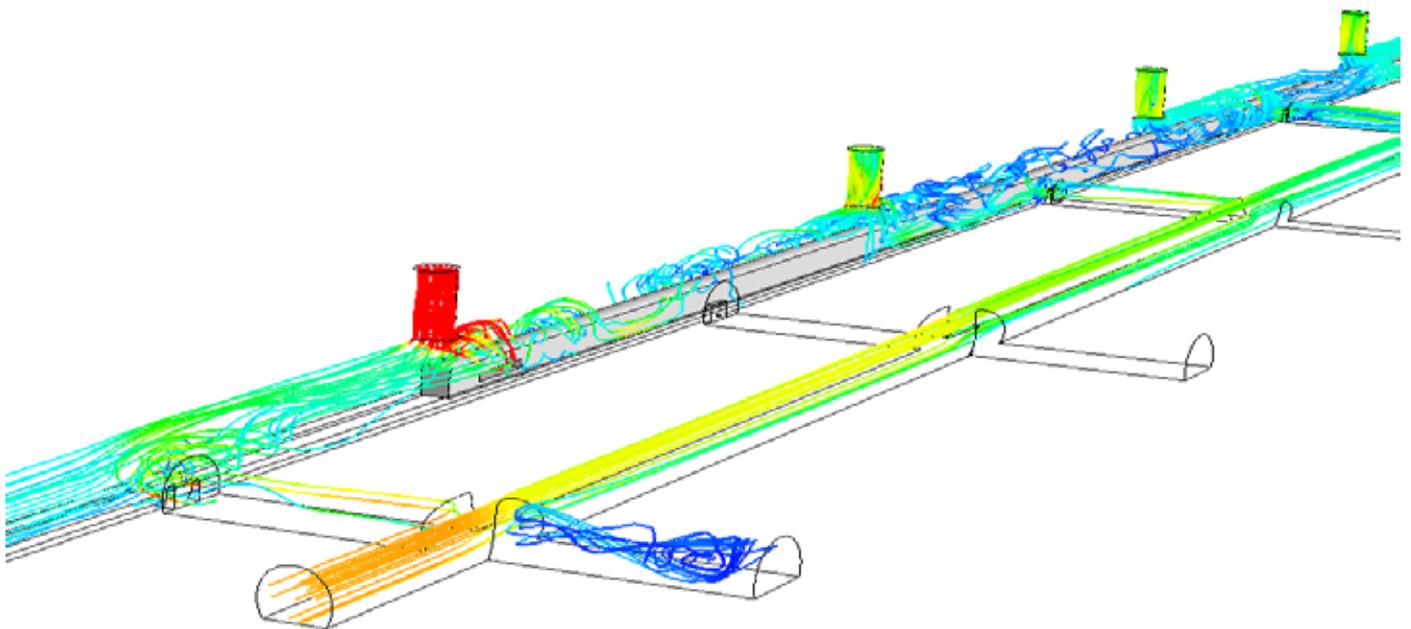
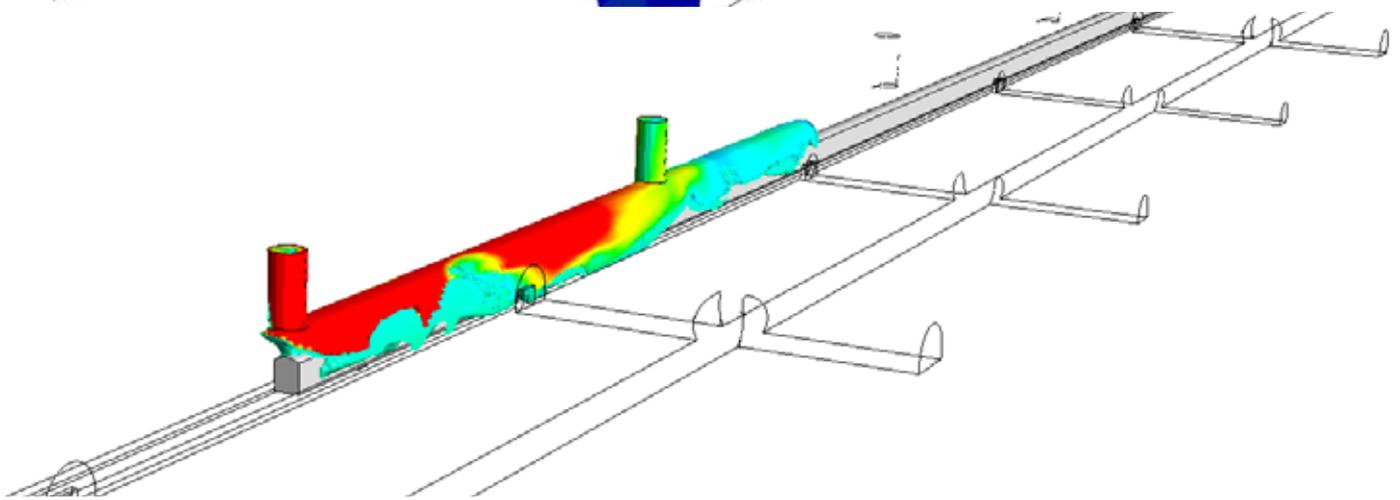
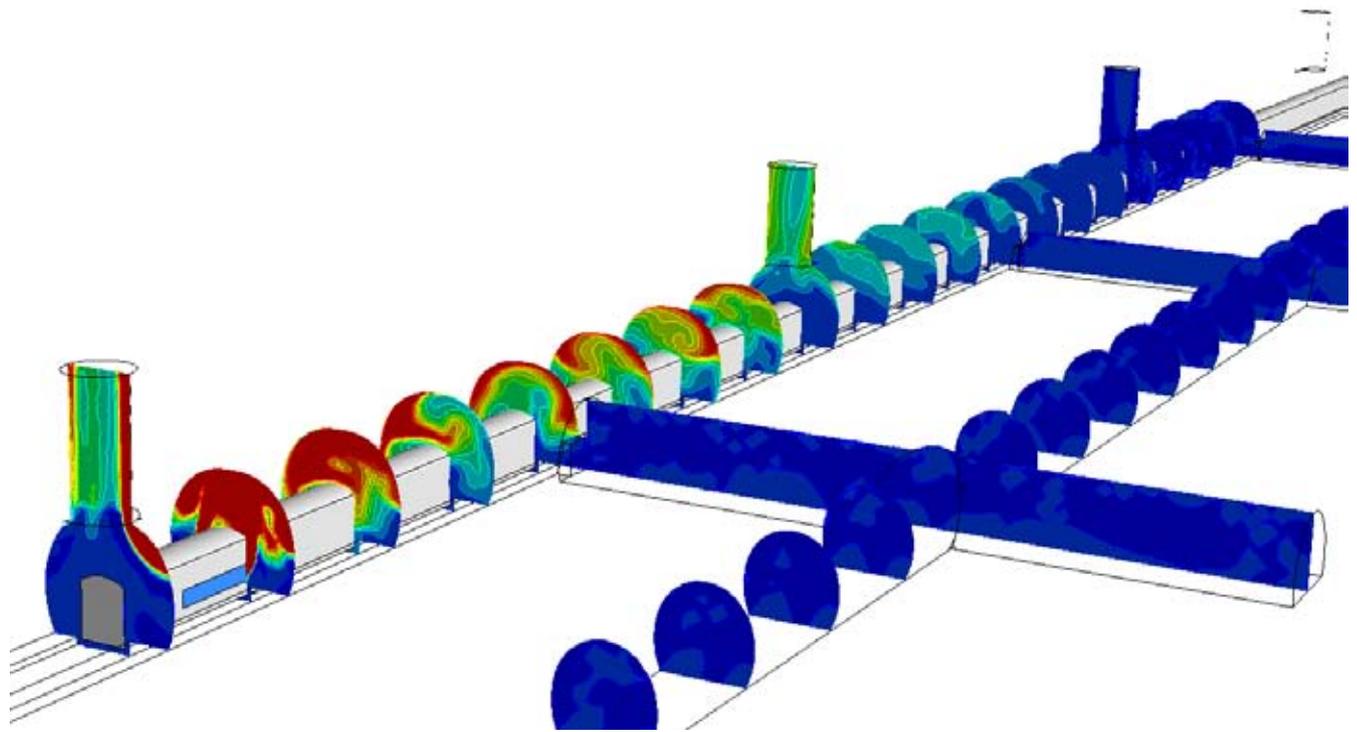
NUMSTA is being continuously developed by qualified experts at ILF. New functions can be added to satisfy the requirements of each individual project.

The software simulates the ventilation of complex road and rail tunnels, taking gravity and temperature effects into account. As a consequence, it is possible, for example, to investigate air flow in branch systems, the impact of the closure of a damper and the effect of the start-up of a fan. In the field of construction and installation ventilation, NUMSTA is a valuable tool to assess the interaction between air conditioning and air flow.

NUMSTA can also be used to simulate the aerodynamics of trains and road vehicles travelling at very high speeds through tunnel systems of almost any degree of complexity. For the construction of tunnels, it is mainly a matter of establishing what effect the pressure waves generated by vehicles have on adjacent surfaces in the entire tunnel system.

Requirements and questions regarding ventilation and aerodynamics in modern tunnels are becoming more and more complex. That is why it is necessary to carry out the coupled and transient simulation of the pressure, temperature, velocity and density of air in branched tunnel systems with active aerodynamic components and vehicles. NUMSTA helps us meet this challenge.

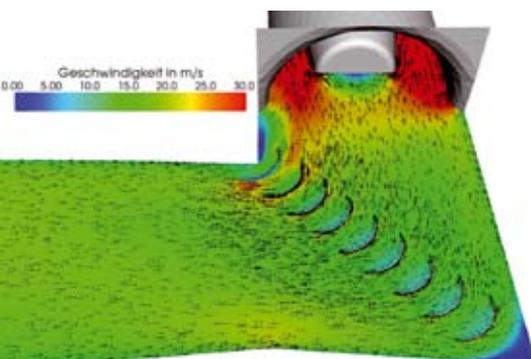




Optimising the details

■ 3D computational fluid dynamics (CFD)

Tunnel ventilation and tunnel aerodynamics mainly deal with the impact of ventilation systems and vehicles on the system as a whole. There are, however, more and more cases, in which local flow conditions play an important role. In connection with tunnel construction, we can, for instance, optimise the flow pattern in the fan intake region, investigate the entry of vehicles into tunnels and support the design of emergency exit ventilation systems. In these cases, air flow is mainly defined by the geometry of ducts and the positioning of ventilation equipment and must undergo 3D calculations. The objective of these calculations is to produce operational reliability and minimise construction, installation and running costs.



To this end, ILF has a powerful scientific computer cluster and state-of-the-art software to process geometric information for the meshing process and for flow modelling. In particularly complex cases, ILF can rely on its longstanding and well established cooperation with companies that specialise in CFD for road vehicles and aircraft.

In the field of tunnel aerodynamics, 3D modelling mainly serves to minimise the excavation volume, optimise the operating range of the fan and increase operational reliability.

■ Smoke spread calculations

The spread of smoke inside and outside a tunnel is an important safety factor for the design of ventilation systems.

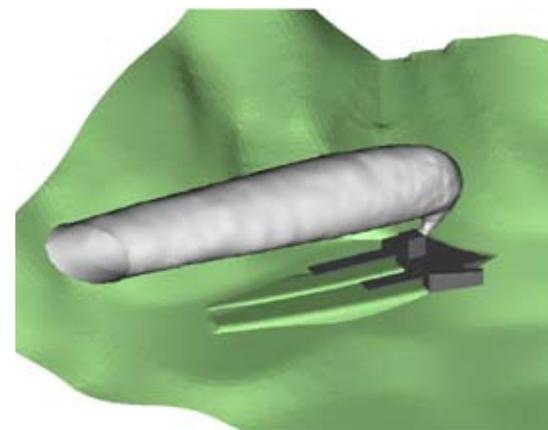
In tunnels, it is important to know the direction in which smoke will move in order to install smoke extraction systems in the right places and to plan suitable emergency response procedure. These calculations are also required for tunnel safety studies that include risk models.

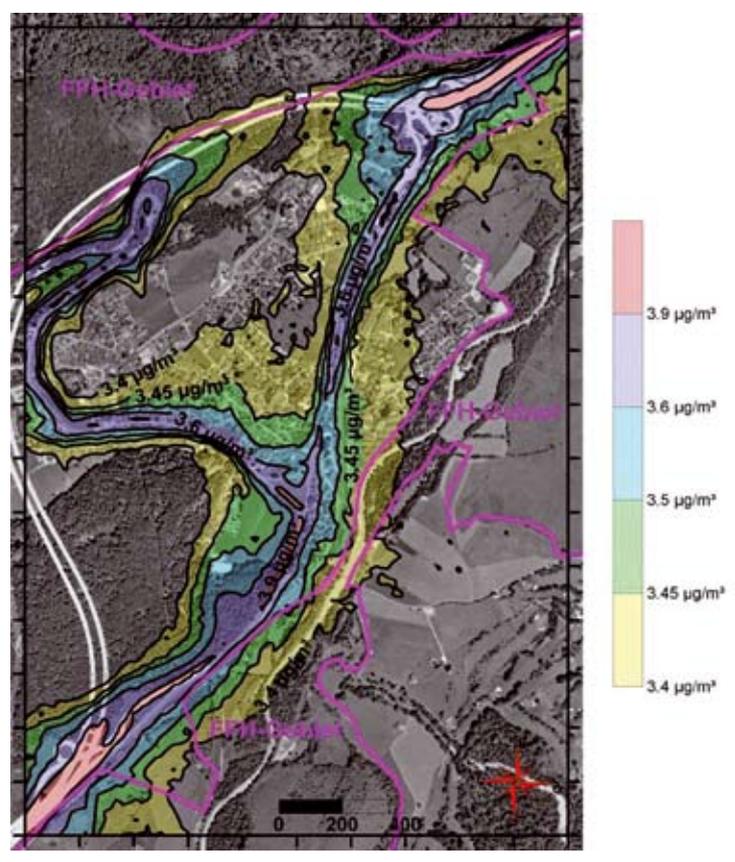
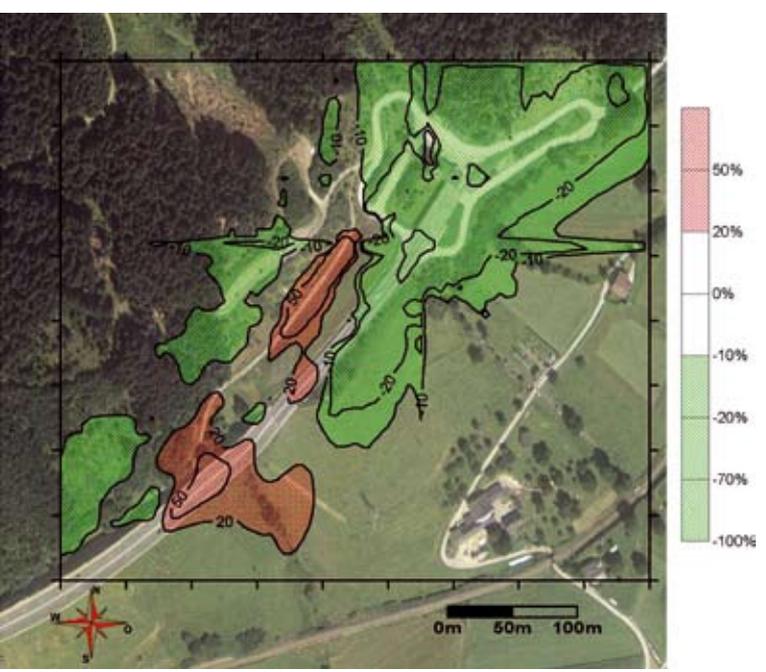
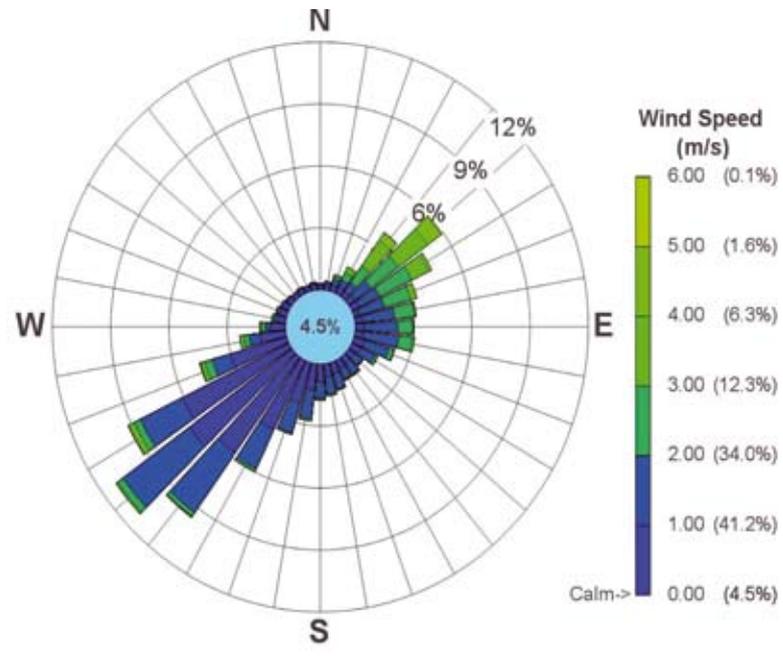
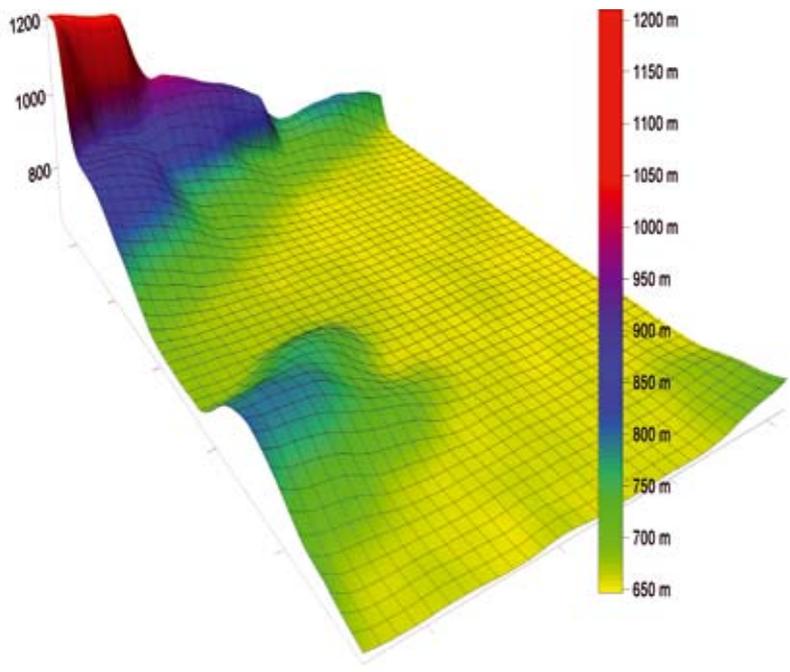
As far as smoke spread outside the tunnel is concerned, it is mainly a matter of preventing smoke recirculation. Exhaust air openings, e.g. the chimneys of portal buildings, must be positioned so that smoke cannot flow back into a tunnel bore where vehicles are still located. The position and shape of smoke vent openings have been taken into account in the early design stage of numerous projects to prevent smoke recirculation even in unfavourable meteorological conditions.

ILF mainly uses the following software packages for CFD and smoke spread calculations:

- OpenFOAM
- Fire Dynamic Simulator (FDS)
- Solvent

ILF has a comprehensive pool of data on fire tests conducted in various tunnels.





Simulation of smoke spread

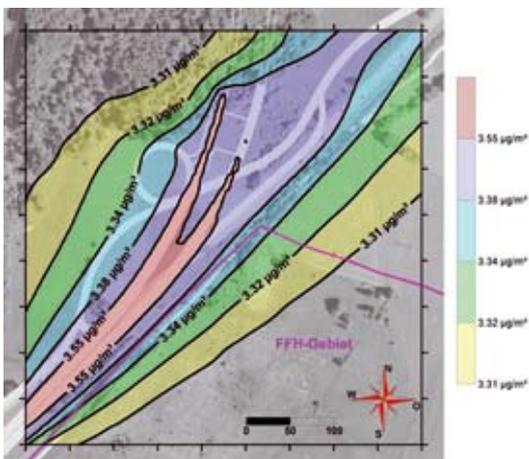
■ Spread of pollutants

Within the framework of environmental impact assessments, more and more authorities and clients are demanding pollution reports. Today, these expert reports are an integral part of the realisation of road tunnels and industrial buildings.

The spread of pollutants can have a decisive impact on the ventilation concept. By combining ventilation design and the assessment of pollutant spread, it is possible to reduce the number of interfaces, minimise sources of error and generate synergies.

ILF uses the following software tools to assess pollutant spread:

- Austal2000
- GRAL35TM
- Breeze Aermod



■ Spread of odours

The calculation of the spread of odours is based on a detailed analysis of meteorological and topological data as well as on an investigation into project-specific traffic scenarios. By using appropriate software, the pollutant concentration in the project area is indicated with isolines. Various forms of visualisation are possible. The forms that are best suited for the project are selected. In the field of public relations, for example, a chart of comparative loads (i.e. pollutant load before and after the realisation of the tunnel) has proven to be very helpful.

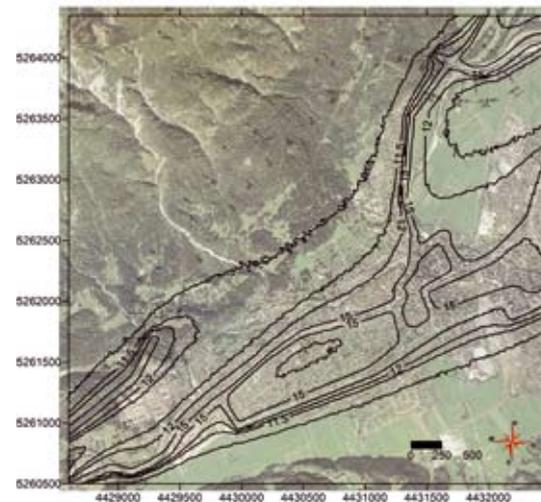
The technology used to simulate the spread of odours and pollutants is also being employed more and more in the fields of water and environment. It is a matter of verifying compliance with threshold values at a very early stage of the project. Examples in this context are waste water treatment works and industrial plants.

ILF offers the following calculations of pollutant spread:

- the spread of any kind of gas
- the spread of dust particles of any size (PM 2.5 - PM 50)
- the deposition of any kind of gas, e.g. nitrogen deposition
- dust deposition

The evaluation of results can be presented in various forms, including the following:

- Mean annual pollutant concentration
- Peak pollutant load
- Evaluation of any percentile value incl. frequency with which ceiling is exceeded





ILF Consulting Engineers offers design and consulting services in the fields of energy, water and environment, oil and gas, construction and infrastructure sectors. Our clients rely on ILF's comprehensive capabilities and professional know-how that the company has acquired in more than 40 years.