Ventilation with Safety

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The Changing Role of Tunnel Ventilation

Ventilation has always been a key issue for the construction and operation phases of both road and rail tunnels, for only through the provision of adequate ventilation (and possibly cooling) can a safe and comfortable environment be guaranteed for underground workers during the construction phase and for passengers during operation.

The role of tunnel ventilation, whilst always being a key one, has however changed significantly over the last decade. Successive regulations in Europe and North America have reduced the allowable vehicle emissions dramatically, leading to a reduced ventilation requirement during normal road tunnel operation. At the same time, serious fires such as the one in the Mont Blanc and Tauern tunnels last year have forced European policy makers to review the issues regarding safety in existing road tunnels, including the issue of emergency ventilation systems and of single versus dual tube tunnel configuration. The impact of these reviews are not limited to road tunnels - the lessons to be learnt may also have an impact on the rail tunnel developments in Europe and elsewhere.

From the perspective of designers and consultants such as HBI Haerter Ltd., the increasing complexity of client requirements has meant a move towards more technologically advanced tools such as Computational Fluid Dynamics for the calculation of three-dimensional flows in tunnels, coupled with the application of practical experience regarding the behaviour of both equipment (such as fans, dampers and louvers) and people (when considerations of evacuation are paramount). This is best illustrated through some examples.

Gotthard Base Tunnel

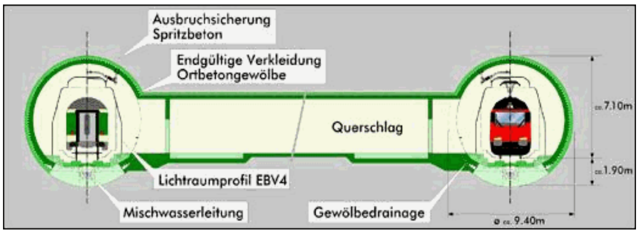
With a length of 57 km, the Gotthard base tunnel will be the longest tunnel of the new high capacity north-south rail links through Switzerland, and indeed the longest tunnel in the world.

The main elements of the Gotthard base tunnel are shown on Fig. 1. The tunnel system is based on a physical separation of the two tracks (twin tube system). The two tubes are connected by cross-passages (every 325 m) and two cross-overs located at the basis of the access points Sedrun and Faido.

The safety concept of the Gotthard base tunnel foresees two emergency stations which are located at Sedrun and Faido. These stations are situated just before the location of the cross-overs. In the event of an incident in the tunnel, passenger trains reach the next rescue station or portal in less than about 20 km. Passengers can escape into a protected, pressurised area to wait at safe distance from the fire for an evacuation train to come. The evacuation takes place using the opposite platform of the rescue station. To account for the risk of train fire the platforms of the emergency stations are ventilated through the open access doors and smoke is exhausted from the tunnel.

If a burning passenger train has to stop between two stations, the passengers escape through the cross-passages and reach a safe haven in the second tube.

The evacuation of the passenger follows over the opposite tube with a regular (empty) passenger train. The evacuation train enters the railway tunnel from the north or the south portal. It is not planned to use the access galleries in Amsteg, Sedrun and Faido for evacuation purposes. Special rescue and fire fighting trains are available near the portals for fighting the fire in the incident tube.



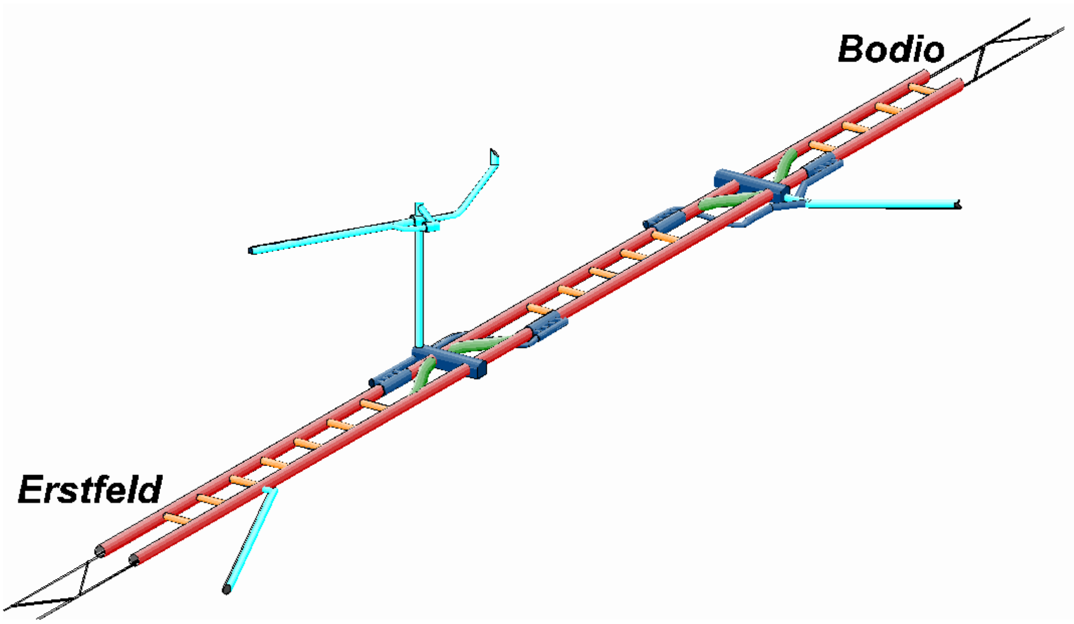


Figure 1: Gotthard Base Tunnel (please note that the picture is not to scale and that the number of cross-passages is much greater in reality). Picture courtesy of AlpTransit Gotthard AG.

Review of Existing Road Tunnel Ventilation Systems

With the reductions in the general level of vehicle-generated pollutants, safety considerations are becoming paramount in the design and dimensioning of road tunnel ventilation systems. New engineering tools that can aid in the design process include Computational Fluid Dynamics, which can help designers to limit the expected spread of dangerous smoke in a fire scenario (see Fig. 2).

It has been generally recognised by public authorities that not just newly built road tunnels should be designed to the relevant standards, but in addition, existing road tunnels should be reviewed to determine whether their emergency ventilation and other safety systems correspond to today's requirements. For example, after two serious fires in the Gotthard road tunnel in 1997 involving a coach and a vehicle transporter, HBI Haerter Ltd. were engaged to review the ventilation design and to recommend improvements. The engineers at HBI dynamically simulated the two fire scenarios using the recorded traffic and meteorological data, and obtained results for extent of smoke spread that corresponded well to that observed during the two incidents. On the basis of that knowledge, the engineers recommended a change in the ventilation control system to improve the emergency response both during the initial evacuation phase and also for the subsequent fire-fighting phase. Today, the engineers at HBI are studying the emergency ventilation system in the Mont Blanc tunnel with a brief to improve that system's effectiveness.

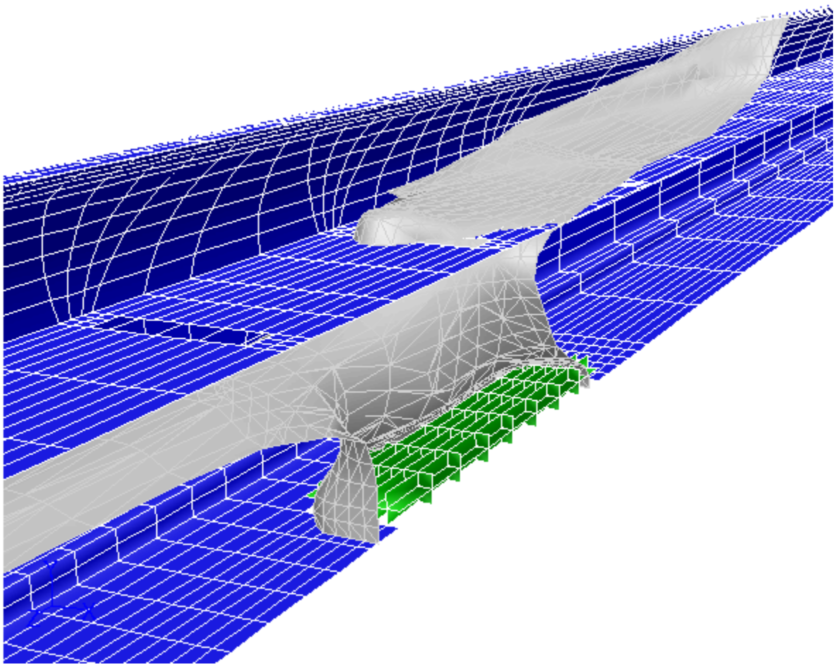


Figure 2: Calculations of smoke spread in a road tunnel using Computational Fluid Dynamics

Simulation of Climatic Conditions during Construction

The planned base-tunnel at Lötschberg is an essential part of the new network of railway connections through the Swiss Alps. Its length of 33 km and the cover of rock extending to a depth of 2000 m pose particular demands on the ventilation and cooling of the work areas during the construction period. An acceptable climate is a major prerequisite for the safety of personnel during construction.

Supply of fresh air and removal of used air have to be maintained over long distances. Expected rock temperatures of partly over 40 °C and the intensive use of heavy duty technical installations lead to significant emission of pollutants and heat into the tunnel system. Despite these unfavourable conditions, ventilation and cooling must create the required air conditions in the working area, i.e. reasonable temperature, humidity levels and air quality. As part of its continuing involvement in the project, HBI Haerter Ltd. was requested to assess the technical requirements and to propose feasible solutions.

The starting point was the design of a ventilation concept including the specification of air flow rates and air directions (see Fig. 3). Major design aspects for the ventilation system were possible releases of methane from rock and fire scenarios at different locations. Based on this ventilation concept, the engineers at HBI calculated the development of air temperature and humidity using a specially developed computer programme. This programme enabled the continuously changing geometry of the tunnel system during the construction phase to be modelled (see Fig. 4). The effect of cooling installations was also simulated, which then enabled the necessary cooling capacity to be calculated. For areas reaching high temperatures, local air coolers with heat pumps providing a thermal cooling load of about 1 MW were proposed. Back-cooling capacity for the heat pumps is provided by fresh water supplied from the portal.

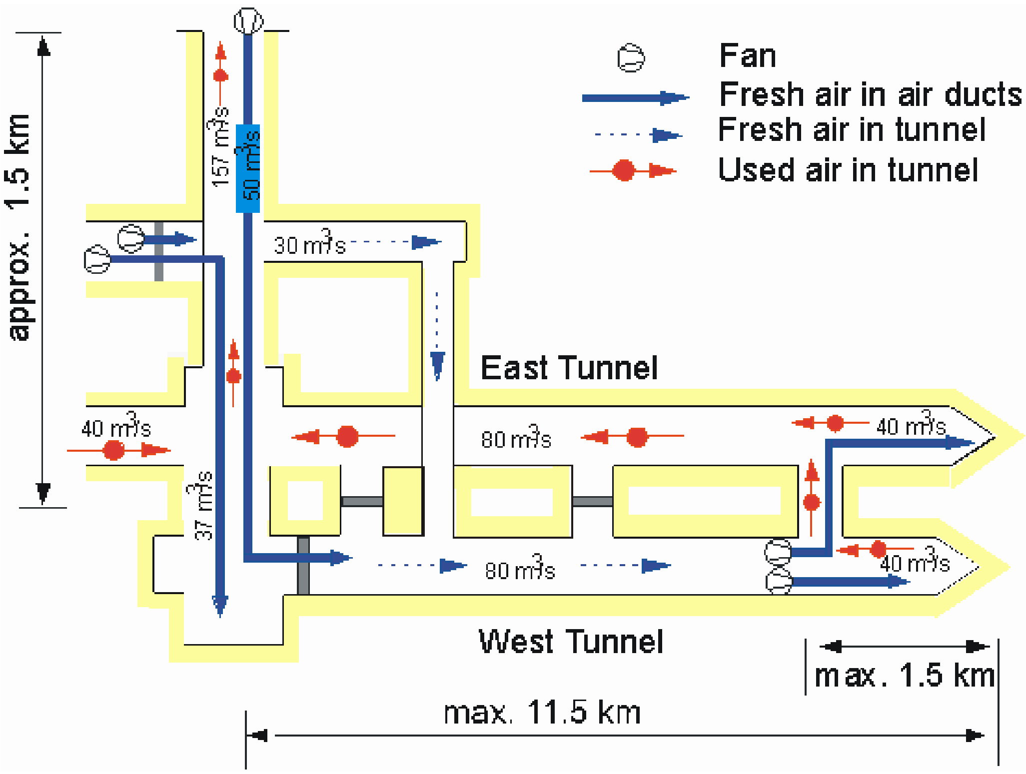


Figure 3 : Air flow rates for the construction phase of a section of the Lötschberg Tunnel as basis for temperature simulation

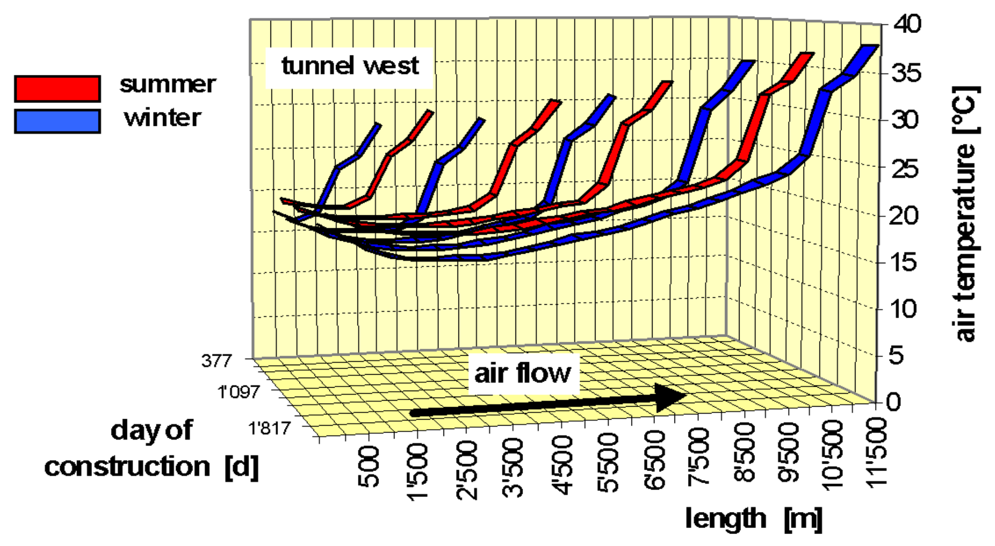


Figure 4 : Temperature simulation for construction period taking into account the continuous increase in length for a tunnel section with longitudinal ventilation (without cooling measures)

Emergency Ventilation in the Longest Rail Tunnel in Korea

In October 1999, Korea National Railroad announced the award of a design-and-build contract for the construction of the 17.8 kilometre long Young Dong Railroad Relocation Project to a consortium led by Daewoo Corporation. The project includes 16.3 kilometres of new, mixed traffic, single track, rock tunnel in the mountains of eastern Korea (Fig. 6). The tunnel, to be driven by drill-and-blast methods, features a large radius loop to give the required gradients between Dong-Baek Mountain Station and Do-Ge Station.

As part of the Daewoo Consortium, HBI were engaged by Halcrow Asia Partnership Ltd. to advise them on the design of the ventilation and risk control systems. The proposal by HBI Haerter to provide a rescue station at a crossing loop in the tunnel, complete with emergency ventilation through a deep shaft, was a key feature of the winning tender.

In a fire emergency, ventilation fans control smoke flow and allow safe evacuation to the neighbouring platform, from which evacuation trains can safely collect passengers (Fig. 6). By employing an appropriate mixture of emergency ventilation equipment and train operational rules, the risks to the travelling Korean public can be reduced down to low European levels.

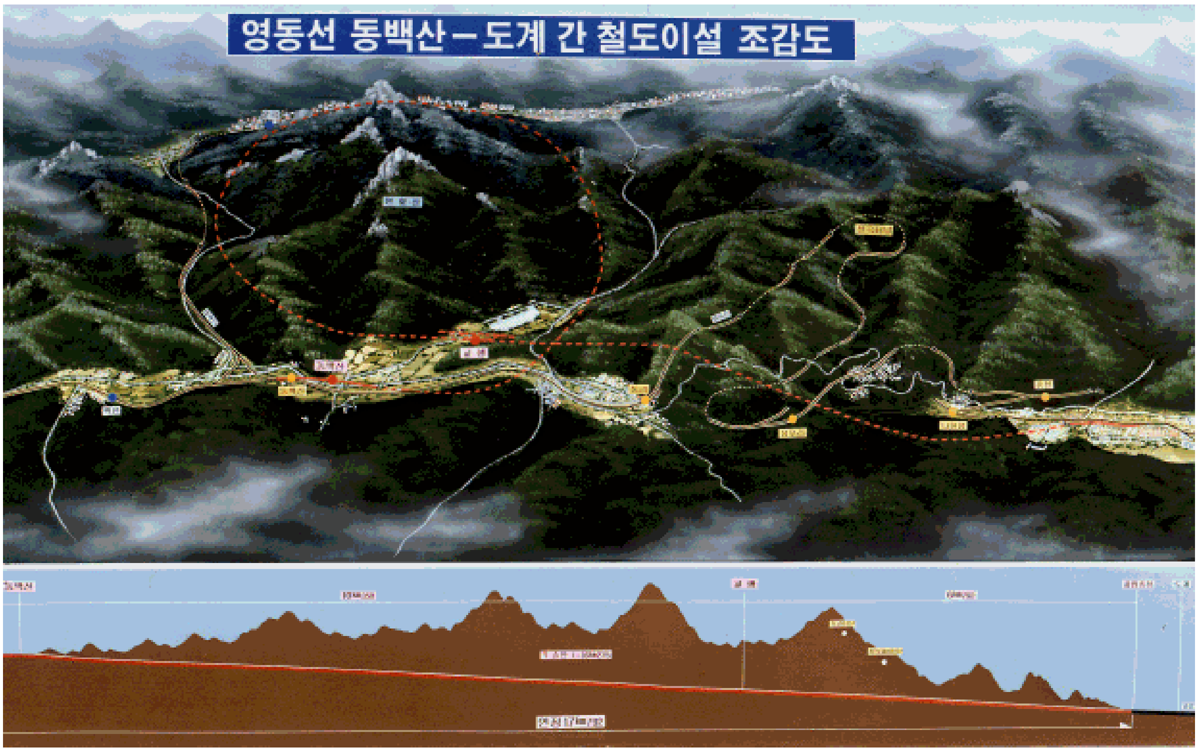


Fig. 5: Overview of the Young Dong Rail Tunnel

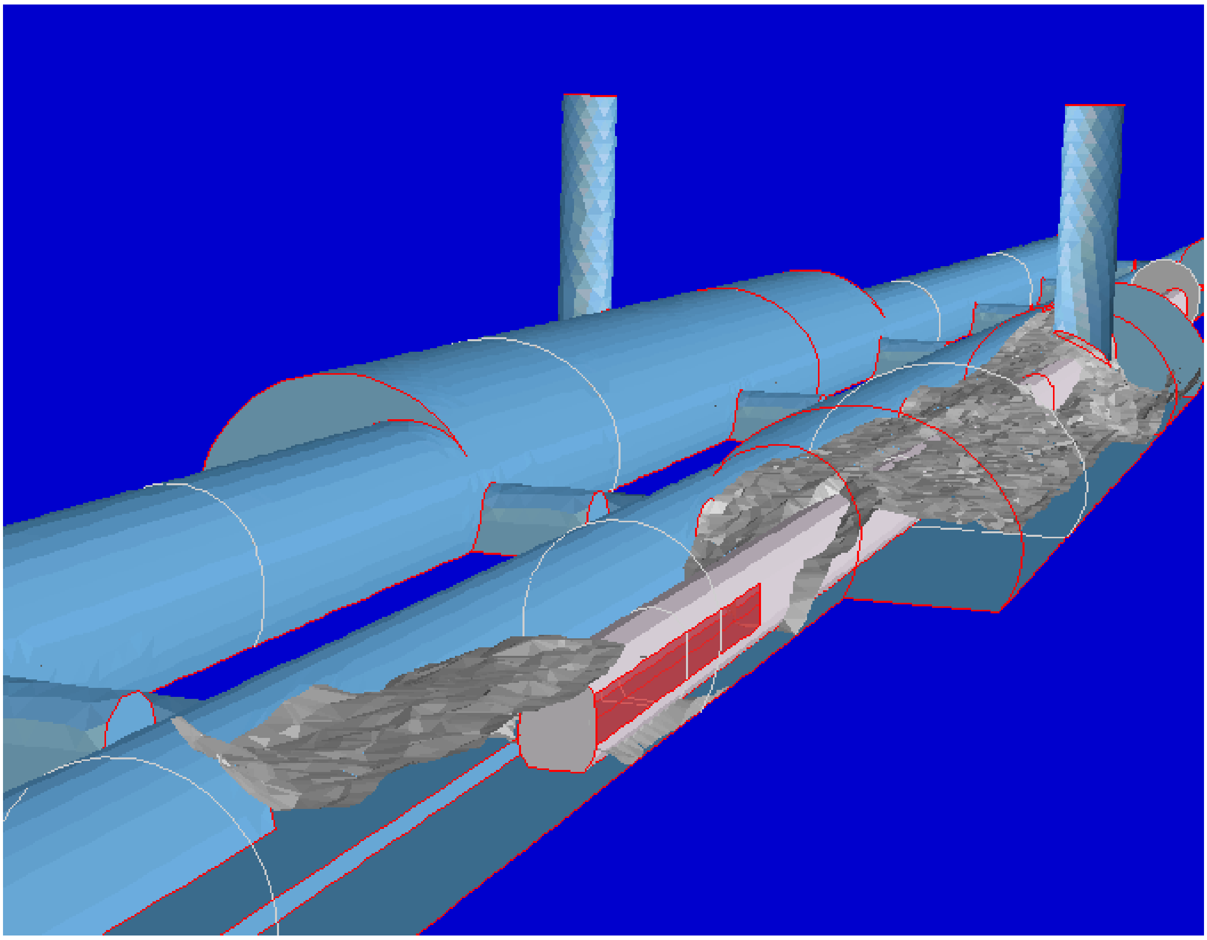


Fig.6: CFD computation of smoke propagation in the rescue station