FIRES IN ROAD TUNNELS IN EUROPE
– IMPACT ON TUNNEL SAFETY IN GERMANY

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ABSTRACT
Based on new findings from the devastating fires in tunnels in some Alpine tunnels in 1999 and 2001, the requirements to the safety of road tunnels were fundamentally revised and supplemented. The national bodies of rules and regulations were revised accordingly for this purpose and were introduced in Germany with the RABT 2003 as a standard for tunnels that were to be newly built in the area of federal highway roads. The federal states of Germany have largely taken over these regulations for state and county roads and have recommended their use for communal roads as well. On a European level, the EC directive 2004/54 (EC tunnel guideline) was decided upon by the European parliament, in which the minimum requirements on the safety for tunnels in the Trans-European Road Network (TERN) are laid down. The EC directive was converted to national law with the introduction of RABT 2006. Already in 2002 the Federal Ministry of Transport, Building and Urban Affairs concerned introduced an extensive retrofitting program for road tunnels in Germany to adapt existing tunnels to the new safety standard as quickly as possible. The main part of the retrofitting program will be finalized by 2010. On the one hand, a short term immediate program was implemented and a long term extensive retrofitting program for the more complex measures was agreed on to speed up effective measures for the increase on tunnel safety in existing road tunnels. A considerable part of the measures could already be finalized. Maintaining records of the body of rules and regulations at a high level will continue to be guaranteed by the initiation and financing of national research projects on tunnel safety on the part of the government in connection with the international research activities going on at present.

1. INTRODUCTION
After the devastating accidents caused by fire in 1999 in the Montblanc tunnel and in the Tauern tunnel as well as in 2001 in the Gotthard tunnel, the subject of tunnel safety has become particularly high priority both on a specialist as well as on a political level. There had to be acknowledgment of the fact that, in spite of modern equipment and operating systems the possibility for tunnel users to save themselves in the case of such extreme accidents - in the first few minutes after the occurrence of a fire - are not sufficient. Recovery by others also did not go too well in all cases and there is room for improvement here as well. The consequence of this was a variety of activities on a national and international level where current experiences were exchanged and new research results were introduced. Although the safety standard in Germany is already relatively high when compared internationally, all measures were once again put to the test and possibilities for improvements were worked out. The results have meanwhile been included in the body of rules and regulations and are being continuously implemented within the framework of extensive retrofitting programs in existing tunnels as well. The financial scope of the retrofitting program is approx. 300 Mio. €, and about 25 % covers structural measures and 75% operational retrofitting measures. The retrofitting program will be largely completed by the year 2010. The requirements according to the new EC tunnel directive will be exceeded in many cases in the process, which, however can be justified, particularly with respect to the high traffic loads in German road tunnels.
2. NUMBER OF TUNNELS

The number of tunnels along the federal highway roads on the effective date of 31st December 2004 was a total of 202 tunnels with a total length of 191 km (Figure 1). The total number including the road tunnels in federal state, county and communal roads is 310 tunnels with a total tube length of 250 km. The aging pattern shows, that the number of tunnels compared to other structures in the German road network is still relatively new and has increased disproportionately in the past 15 years in particular. Thus, the number of road tunnels on federal highway roads has more than doubled between 1992 and 2004 alone. The reasons for this are, on the one hand, increased requirements to noise protection and protection of the country side that can only be realised in sections by covering the roads, as well as, on the other hand, the often cramped conditions at by-passes which increasingly require routes with tunnels.

About 53% of road tunnels on federal highway roads are tunnels with only one tube that are operated with bidirectional traffic. There is a need for retrofitting according to requirements here, particularly in the case of longer tunnels with a high traffic load, to optimise the ventilation systems, for example and to improve the possibilities for saving yourself using additional escape routes.

![Figure 1: Number and tube length of main road tunnels in Germany](image)

3. EC TUNNEL DIRECTIVE AND RABT

Safety requirements to road tunnels refer both to structural measures as well as to the operational fitting of the tunnel in particular. The structural requirements with respect to dimensioning, design and structural fire protection, for example, are regulated in the “Zusätzliche Technische Vertragsbedingungen und Richtlinien für Ingenieurbauten (ZTV-ING)” Part 5, tunnel construction; operational requirements with respect to ventilation and lighting, escape possibilities and safety equipment, for example, are compiled in the “Richtlinien für die Ausstattung und den Betrieb von Straßentunneln (RABT)”’. The usual fittings according to RABT are shown in Figure 2.

![Figure 2](image)
The 2003 edition of RABT already took into account the latest findings and measures with respect to safety, which were a result of the intensive discussion amongst experts after the fires in tunnels. The level of the requirements is over and above the EC tunnel directive in many points. RABT 2003 started with the main objective of personal security, for which the operational and structural measures have to be laid down first. The extent of safety measures mainly depends on the length of the tunnel. Apart from this, the proportion of heavy traffic can be essential for individual components, for example, when determining the strength of the fire concerned.

According to the indications in the EC tunnel directive, it was to be converted to national law by May 2006. This took place in Germany by recording RABT 2003, for which, apart from minor adaptations to the safety requirements, it was mainly additions to administrative and organisational regulations as well as documentation, registration and reporting duties that were required. An important point in this case is that the requirements of the EC directive were not only converted for the German road tunnels belonging to TERN, but for all tunnels in the federal highway road area. The conversion of the EC directive is now available in an updated form as the 2006 edition of RABT.

4. MEASURES FOR SAFETY RETROFITTING

At first the road administrations of the federal states, that design, construct and operate federal highway roads within the framework of contract management for the government, were requested, to subject all tunnels to an appropriate testing to obtain as complete an overview as possible on the extent of necessary safety equipping of existing road tunnels. The RABT 2003 catalogue of requirements was important for this purpose. The necessary measures for this were differentiated according to structural and operational retrofitting. An initial cost estimate had to be given for the measures at the same time, which must be indicated more accurately later for a larger scope using corresponding design documents.
The following points had to be checked, amongst others, for a possible structural retrofitting:

- distance of emergency exits
- position of escape galleries
- position of lay-bys
- crossing of the central reserve outside each portal
- drainage system, slot gutter
- fire extinguishing line, hydrants
- water supply at the portals
- support basin for disruptive incidents
- position of intermediate ceilings
- installation of emergency cabins

The following points also had to be checked, amongst others, for a possible operational retrofitting:

- ventilation system, fire ventilation
- normal lighting, evacuation lighting
- current supply, emergency power supply
- emergency stations at the entrances/exits
- emergency cabins in the tunnel
- video monitoring system
- fire detection
- fire-fighting equipment
- radio broadcasting for emergency services
- function of loudspeaker system
- traffic engineering equipment
- road signs in front of and inside the tunnel
- escape route signs
- lane indicator system

Apart from the enquiry for the requirement for structural and operational retrofitting measures, organisational measures were also requested. This included

- the availability of alarm and evacuation plans
- execution of regular practices and
- monitoring by control centres.

When testing the required measures and the conversion that has already started at the same time in some states, it very soon became clear that the safety facilities in tunnels in particular, that are of significance for the tunnel users to be able to save themselves, must be formed in a uniform manner in all tunnels. However, since RABT 2003 did not give sufficient specifications for all points for this purpose, guidelines for a uniform appearance of the tunnels with reference to the facilities relevant to users were worked out immediately. These refer, amongst other things, to the

- designing of escape route markings
- designing of self-illuminating guide markings on emergency walkways with alternative use as escape route markings in the case of fire,
- colour coordinated design and marking of emergency exits (Figure 3) and
- colour coordination of the emergency cabins.
These uniform design guidelines have meanwhile been introduced in the area of federal highway roads and were included in RABT 2006.

5. MEASURES

An initial evaluation of the necessary measures was carried out by the Federal Highway Research Institute on behalf of the Federal Ministry for Transport, Building and Urban Affairs based on the check lists to prepare a list of priorities with a corresponding weightage. The retrofitting programs covering several years could be then be compiled from this list of priorities after agreement with the road administrations of the states.

The project specific list of measures soon showed that particularly for older tunnels, for the preparation and conversion of the measures, partly extensive experts’ opinions were necessary, for which the processing would take a considerable amount of time. The financial and personal capacity of the respective road administrations also had to be considered for the majority of projects in the individual states. For this reason, two retrofitting programs were developed:

An immediate program with measures of a smaller scope, but which already contribute to a clear increase in the safety in tunnels and improve the possibilities for tunnel users to save themselves, in particular.

The actual retrofitting program with extensive measures, which partly covers an extensive modernisation of the entire tunnel equipment or includes larger structural measures that can often only be carried out with complete closing of the tunnel tube.

Immediate measures should preferably be carried out in still relatively new tunnels with fewer requirements for retrofitting or in tunnels where extensive retrofitting is only planned in a few years due the laborious preliminary investigations. The main objective is the improvement of personal security by the following measures, amongst others:

- Improvement in the recognition of technical failures, e.g. through a concentrated acquisition of traffic data connected to traffic influencing units and video technology
- More effective automatic closing of tunnels in the case of accidents through the additional installation of barriers at tunnel entrances
Optimisation of the recognition and localisation of fires through the further development of detection systems
Improved ventilation and measures for smoke to escape faster from the tunnel tubes
Faster and more specific information to the tunnel users thorough flawless reception of traffic radio and improvements to loudspeaker technology
Improvements to the escape route systems by reduction of the intervals between the emergency exits and by building additional rescue corridors.
Clearer marking of the escape routes through uniform pictograms connected to fire emergency lighting and lane indicator systems.

A large number of immediate measures could be carried out meanwhile and numerous extensive retrofitting could be completed. With the ambitious objective of completing the main tunnel retrofitting program by the year 2010 Germany would have finished tunnel retrofitting even before the deadline given in the EC tunnel directive.

Apart from this, national research projects are being financed at present using government funds for research to clarify individual issues on measures for tunnel safety. This includes, amongst others:

Detection of fires and accidents in road tunnels – Comparative investigations
Experiments with fires in road tunnels – Standardisation of execution and evaluation
Assessment of safety in road tunnels
Design of emergency exits in road tunnels
Fire reaction of tunnel wall coatings
Safety of Lives in Tunnels (SOLIT) (promoted by the BMBF)

As in the case of the results of the international research projects and activities (e.g. PIARC) currently under way, the results of the above mentioned activities will also be taken into consideration when maintaining records of the relevant bodies of rules and regulations and thus guarantee a safety standard in tunnels on federal highway roads corresponding to the present state-of-the-art in future as well.

REFERENCES:


