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Safety in Tunnels
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SAFETY OF TUNNELS

Research Project FE 82.166/1999/B3 of the German Federal Highway Research Institut (BASt), Bergisch Gladbach, Germany

Final Report (December 2000)

Extracts from the Working Group on ROAD TUNNELS

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Abstract

In the case of fire in German road tunnels a high level of safety is reached today already with the measures taken for the protection of people. This is proven by the fact that e.g. the last big fire in a German road tunnel took place in 1968 (Moorfleet, Hamburg), where there were no casualties. Especially with respect to road tunnels a recent investigation has come to the conclusion that

tunnels in Germany are after all road sections with an extremely low accident risk and even the accident costs are lower in tunnels.

However, recently fires have taken place, e.g. Mt Blanc and Tauerntunnel, which lead to substantial losses of lives and to heavy constructional damages. These fires were the reason to investigate whether the protection of people in cases of fire in German road tunnels has to be even more increased. Against this background a Federal Highway Research Institute of Germany (BASt) Workshop "Safety in Tunnels" was held with the aim to discuss with experts the possibilities of further increasing the protection of people in cases of fire in German road tunnels.

The aim of the research project was to document the BASt-Workshop, to analyse cases of fires in tunnels, to establish proposals for the increase of the protection of people in cases of fire in road tunnels and to propose recommendations for the amendments of important guidelines.

The discussions of the BASt-Workshop, the case histories of fires from literature and the special information about cases of fire from German and foreign tunnel owners were evaluated. A total of 33 fires in road tunnels were investigated. The main reasons for fires in these tunnels were vehicle-defects. Problems occured during fire-fighting and rescue operations due to bad visibility because of rapid smoke development and because of the lack of an optimal safety and rescue concept.

After finishing the evaluation the following proposals were made for further increasing the protection of people in cases of fire:

1. **Optimisation of fire detection and location of the fire**
2. **Improvement of the traffic management in detecting unusual cases**
3. **Efficient automatic barriers in front of tunnel portals**
4. **Rapid and direct information for tunnel users**
5. **Improvement of escape route systems**
6. **Better marking of escape routes**
7. **Improvement of smoke control**
8. **Improvement of communications between all services**
9. **Early detection of vehicle defects**
10. **Automatic fire-fighting systems in vehicles**
11. **Optimisation of equipment for all services**

Structural improvements for the safety of tunnel users should be taken first, before installing more sophisticated technical equipment.

The committees in charge should prove if and how the proposed measures for further increasing the protection of people in cases of fire should be implemented within the guidelines for the construction and the operation of road tunnels.

Recommendations for the improvement of the safety of users in cases of fire in guidelines for German road tunnels

The following recommendations for the improvement of safety of users in cases of fire in German road tunnels should be critically investigated by the responsible authorities with respect to feasibility.

The German guidelines for road tunnels (ZTV-Tunnel, RABT) should be updated and amended in order to improve the safety of users in cases of fire with the following measures:

1. Improvement of automatic fire detection

The guidelines should require automatic fire detection systems with short time response.

2. Improvement of CCTV-systems

The German guideline RABT already requires in specific cases (e.g. long tunnels with high traffic volume) traffic surveillance with CCTV. The use of this equipment increases traffic surveillance substantially. The use of video technology for the early detection of certain cases (break-downs, traffic congestion, accidents, fires) seems to have great potential. Different systems are already on the market and should be tested for their usability.

3. Emergency cabins

In the future the emergency points according to the RABT should be manufactured as noise-protected emergency cabins. A better understanding between the users at the emergency point and the operators in the emergency central unit would be achieved through this noise protection measure.

4. Traffic Management Systems

a) The guidelines should require that the distances between heavy goods vehicles and the speed of vehicles in tunnels should be better controlled, in order to reach a more unified traffic flow and consequently also greater safety in tunnels.

b) The guidelines should recommend that tunnels with high traffic volumes should have traffic management systems which can avoid traffic congestion in tunnels. The traffic should flow in such a way that after an incident unaffected vehicles can leave the tunnel quickly.

5. Improvement of tunnel closures

The guidelines should propose the enhancement of tunnel closures by using in addition to changeable traffic lights also mechanical barriers.

6. Improvement of tunnel surveillance

a) Operational centres

The RABT should consider whether it is necessary for certain tunnels (e.g. high traffic volumes, long tunnels) to have a control room. In case a number of tunnel control rooms are necessary within one region, it should be checked whether surveillance of these tunnels could be joined together by the transmission of video signals and operational data into a single operational centre.

b) Safety officer

It should be investigated, if a safety officer, who is responsible for the preparation and control of safety and rescue concepts, should be put in place for a single or more tunnels in the future.

7. Loudspeakers

The RABT should recommend loudspeakers only if they are useful, e.g. at traffic signals before tunnel portals or in cross connections during evacuation. In tunnel tubes they are often useless because of the existing noise.

8. Information of users in cases of fire

The guidelines should account for announcements in different languages (e.g. the demand for immediate escape) via broadcasting or with internationally harmonised changeable traffic signs.

9. Reduction of distances between emergency exits

a) Length of tunnels with emergency exits

In the RABT the minimum length of future tunnels with mandatory emergency exits should be decreased to around 400 m to 500m (at the moment 700 m). This is especially necessary for bi-directional tunnels.

b) Distance between emergency exits

The current RABT allowable maximum distance between emergency exits of 350 m should be reduced to around 300 m. A greater distance should be allowed only in cases where other measures (e.g. ventilation) can assure that escaping users can reach a smoke-free tunnel section after around 300 m.

According to the type of construction the RABT should recommend e.g. cross connections between parallel tunnel tubes, emergency galleries and emergency lanes below the carriageway, if the cross section of the tunnel allows these.

10. Emergency galleries with bi-directional tunnels

The guidelines should propose a separate emergency gallery not dependent on the ventilation system in cases of tunnels with high risk potential, e.g. long bi-directional tunnels with high traffic density (traffic volume times tunnel tube length) and high longitudinal gradients.

Exceptions can be made, if it is economically not acceptable to build a separate parallel emergency gallery. In this case a quantitative risk analysis has to show that according to existing equipment, e.g. an improved ventilation system with optimised other tunnel techniques (e.g. improved fire detection, optimal rescue- and fire-brigade operation) a separate emergency gallery is not necessary.

11. Calorific power of fires for the design of ventilation measures

The existing RABT looks so far only at single fires and not at fires with more vehicles involved. Therefore in the RABT a high calorific power of 20 MW is taken for heavy goods vehicles up to 15% of the AADT value together with a smoke flow of 60 m^3/s for the design of the ventilation. If the percentage of heavy goods vehicles is above 15% of the AADT the calorific power should be taken between 30 MW and 50 MW together with a smoke flow between 90 m^3/s and 150 m^3/s for design.

These measures should be altered as follows:

a) for design a heavy goods vehicle should be taken,

b) the calorific power should be in a range between 30 MW and 50 MW depending upon the absolute number of heavy goods vehicles which pass every day through the tunnel,

c) in cases of very high numbers of heavy goods vehicles with high risk potential an even higher calorific power should be taken. The reasoning for this has to be shown via a quantitative risk analysis expertise.

12. Smoke exhaust ducts

The old sentence of the RABT*: If smoke exhausts are available, escape ways are not necessary* cannot be left any more in the new version.

The RABT should require an investigation of the application limits of ventilation systems and, if necessary, propose amendments, e.g. because of the following advantages of a smoke exhaust duct within a tunnel with high numbers of heavy goods vehicles and high risk potential:

a) the smoke will be taken out from the tunnel ceiling in such a way that dangers from smoke inhalation, lack of visibility and heat conditions for tunnel users and for fire brigades and rescue teams can be reduced significantly.

b) Even in cases of a fire at the end of traffic congestion within a tunnel the smoke can be taken out through functional smoke exhaust ducts, thus insuring that the tunnel users trapped in the traffic congestion are not in a dangerous situation.

13. Ventilation

a) Application limits of ventilation systems:

Checking the application limits of ventilation systems the RABT should distinguish between uni-directional traffic situations without and with frequent traffic congestion. It

should be checked if in unique cases tunnels with uni-directional traffic should be ventilated like bi-directional tunnels.

b) Response time of ventilation equipment:

The RABT should propose a response time to reach full operation for ventilation in cases of fire of less than 2 minutes.

c) Protection of the unharmed tube against intake of smoke:

The RABT should propose fire and smoke resistant escape doors in cross connections between tubes in order to prevent smoke intake into the unharmed tube.

14. Improvement of radio communications

All tunnels in which natural radio broadcasting is not yet sufficient should be equipped with special broadcasting equipment. The RABT should propose such equipment for all tunnels exceeding 600 m in length.

15. Updating of alarm plans

The guidelines should propose regular updating of alarm plans. The fire scenarios for fire fighting and rescue measures should be taken into account especially for cases of fires with high calorific powers.

16. Fire-fighting equipment in vehicles

The committees in charge should verify which of the proposed measures should be implemented within the guidelines :

a) fire-extinguishers should be obligatory for all heavy goods vehicles with high calorific powers
b) automatic fire-fighting equipment should be obligatory for all vehicles transporting dangerous goods and all heavy goods vehicles with high calorific powers (OECD/PIARC groupings A to D)

The RABT proposes fire extinguishers (2 pieces each with 6 kg powder) at emergency stations within the tunnel. These are sufficient to extinguish a fire of a passenger car at the beginning of the fire. Therefore it should not be obligatory to ask all owners of passenger cars to carry a 2 kg fire extinguisher in their vehicle.

17. Improvement of water supply for fire-fighting operations

The RABT should propose the following improvements in water supply for fire-fighting operations in new road tunnels:

a) Installation of a separate water supply

The length of new tunnels, for which a separate water supply with a pressurised main is necessary, should be reduced to 500 m.

b) Distances between hydrants

The distances between hydrants should be reduced in newly built tunnels to values between 100 m and 150 m. Alternatively, in short tunnels hydrants should be installed at the tunnel portals.

c) Pressure in water mains

The RABT should raise the lower limit for water pressure within the water supply for fire-fighting operations, but not beyond 1 MPa, because fire brigades should be able to connect foam extinguishers to the hydrants.

18. Equipment for fire brigades for operation in tunnels

Within the guidelines there should be some remarks about special equipment (e.g. long-duration breathing apparatus, infrared cameras) necessary for the operation of fire brigades in tunnels.

19. Risk potentials in tunnels

The guidelines should propose that the following points be taken into consideration when dealing with risk potential in tunnels:

a) In the future, it should be considered to take traffic density (traffic volume per year times the tunnel tube length in km) as a parameter instead of length criteria, when designing for the equipment of tunnels.
b) High longitudinal gradients can increase risk potential. Longitudinal gradients above 5% should therefore be avoided.
c) When designing for a number of tunnel tubes (bi-directional or uni-directional tunnels) the proposed traffic volumes should first be taken into account as important criteria. However, if there are important additional risks (e.g. under-water tunnel, high longitudinal gradients), these should also be considered in the design for the number of tubes with a qualitative risk analysis in conjunction with a cost-benefit expertise.
d) In uni-directional tunnels with the possibility of daily congestion similar measures should be taken into account as in bi-directional tunnels.
e) In underwater tunnels risk analysis studies should be performed, which could lead to partial or total restrictions on specific transports of dangerous goods through these tunnels.
f) The RABT should in the case of tunnels with high risk potential call for shorter distances between lay-bys (at the moment around 700 m).

20. Risk potential of vehicles

The current requirements of the RABT for the transport of dangerous goods should be reviewed. Unique and understandable regulations should be demanded, which lead to the definition of a few dangerous goods categories and which could be used for the application in quantitative risk analyses. During the evaluation the proposals of the OECD/PIARC study should be taken into account.

21. Improvement of safety during transport of dangerous goods

a) Operation with transit restrictions

In chapter 4 “Transport of dangerous goods” the RABT should call for e.g. the following possibilities for transit restrictions on the transport of dangerous goods:

-no allowances of transit of dangerous goods transports (only in very few cases)
-partial allowance for special dangerous goods
-special transit allowances obtained from the tunnel control centre
-timely restricted transit (e.g. during times of low traffic at night)
-safe transit with escort vehicles
-convoy establishment and safe convoy transit with escort vehicles

b) Control of transit regulations

The guidelines should call for parking lots in front of tunnel portals which could be used for checking dangerous goods vehicles. These parking lots should have an exit to the road system outside the tunnel so that dangerous goods vehicles with no transit allowance can use it alternatively.

22. Automatic fire-extinguishing equipment

In the current development status automatic fire-extinguish systems are seen to be conterproductive in the self-rescue phase in road tunnels and are therefore not recommended worldwide. Therefore the RABT should not demand automatic fire-extinguishing equipment for the time being.