EARLY EXPERIENCE WITH THE ROAD TUNNEL SAFETY LAW

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ABSTRACT

This report deals with the application of the EU Directive 2004/54/EC in Austria under the Road Tunnel Safety Law. Appropriated procedures for the approval of tunnel preliminary drafts and the putting into operation of tunnels guarantee that the minimum requirements are fulfilled according to the Road Tunnel Safety Law 54/2006 and the technical state-of-the-art defined in the Austrian code for the planning and operation of tunnels. Existing tunnels were subject to a first evaluation the data from which together with the safety documentation of the respective tunnel served as a basis for the preparation of a report discussing the level of the fulfilment for the requirements set by the Road Tunnel Safety Law. In the meantime safety reports have been prepared for all motorway and expressway tunnels longer than 500m whether they are in the planning stage, under construction or in operation.

1. INTRODUCTION

The Austrian Road Tunnel Safety Law STSG 54/2006 has been in force since May 2006 and represents an important basis for the planning, construction and maintenance of Austrian roadway tunnels. The implementation of this law is based on the EU Directive 2004/54/EG issued by the European Parliament and the Council on 29 April 2004 which deals with the minimum requirements for the safety of tunnels within the Trans-European roadway network aiming at setting standardised minimum requirements for the safety of European road tunnels. Hence, the guideline contains both regulations regarding minimum requirements for safety facilities and regulations regarding the unification of the design and the providing of notes and information for all European road tunnels in order to unify and simplify the necessary procedures for tunnel users. This concerns primarily facilities serving the purpose of self-rescue, such as indication signs for escape routes, lay bays, emergency phones or fire extinguishers. In Austria the use of these traffic and emergency signs is regulated in the amendment of the road traffic law (STVO) and the road tunnel safety law.

Minimum safety requirements for tunnels longer than 500m are defined by a set of minimum requirement for safety design equipment, by general safety parameters and by operation procedure specifications. In cases of special tunnel characteristics a risk analysis ought to be carried out to establish whether additional safety measures or supplementary safety equipment are necessary to ensure an equivalent safety level.

The safety of a tunnel not only depends on the safety equipment used but also on operational aspects, on the initial and continuing training of operational staff, and road use behaviour. That is the reason why the law for tunnel safety in Austria, in accordance with the related EU Directive, provides a set of organisational measures and procedures to ensure the uniform safety of tunnels.

2. PROCEDURES FOLLOWING THE AUSTRIAN ROAD TUNNEL SAFETY LAW

The Austrian Road Tunnel Safety Law provides several protocols to set minimum safety requirements for tunnels during the planning and operational stage. Regarding the Austrian law, procedures are carried out for the approval of the design before any construction work
begins and for the approval of the tunnel before opening the roadway for public use. These procedures also apply in cases of substantial modification work on existing tunnels, as this may significantly alter part of the constituent components from the safety documentation. When the procedures following the Austrian law for tunnel safety are finished a decision document is prepared which includes conditions and penalties if necessary.

Concerning the EU Directive, special attention was given to the compliance of existing tunnels with the specified requirements set by the Directive within a target date which is set for Austria as 30 April 2019, as Austria is home to a high percentage of tunnels in the Trans-European roadway network. The European Commission required a report of the plan for the refurbishment of all existing tunnels with regard to the EU Directive before 30 April 2007. To comply with these requirements, last year the Austrian administrative authority carried out the first assessment of 59 motorway and expressway tunnels longer than 500m, following the Austrian law for tunnel safety. The report was very thoroughly prepared with review of safety documentation and inspection of each tunnel.

In Austria the implementation of safety requirements focuses mainly on the construction of the second tunnel tube, which has been and will be managed completely by the ASFINAG instead of the very expensive measure. Figure 1 shows a list of the tunnels on motorways and expressways in Austria, which are already built, are under construction or are in the planning stage.

<table>
<thead>
<tr>
<th>Tunnel</th>
<th>Road</th>
<th>Length of the Tunnel [m]</th>
<th>Second Tube opening date /status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selzthal</td>
<td>A09</td>
<td>958</td>
<td>04/2000</td>
</tr>
<tr>
<td>Gräbern</td>
<td>A02</td>
<td>2145</td>
<td>10/2003</td>
</tr>
<tr>
<td>Amberg</td>
<td>A14</td>
<td>2967</td>
<td>12/2003</td>
</tr>
<tr>
<td>Plabutsch</td>
<td>A09</td>
<td>10085</td>
<td>01/2004</td>
</tr>
<tr>
<td>Herzogberg</td>
<td>A02</td>
<td>1956</td>
<td>06/2006</td>
</tr>
<tr>
<td>Assingberg</td>
<td>A02</td>
<td>251</td>
<td>01/2007</td>
</tr>
<tr>
<td>Lainberg</td>
<td>A09</td>
<td>2208</td>
<td>02/2008</td>
</tr>
<tr>
<td>Ganzstein</td>
<td>S06</td>
<td>2100</td>
<td>08/2008</td>
</tr>
<tr>
<td>Tauern</td>
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<td>6546</td>
<td>under construction</td>
</tr>
<tr>
<td>Katschberg</td>
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<td>5418</td>
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</tr>
<tr>
<td>Roppen</td>
<td>A12</td>
<td>5100</td>
<td>under construction</td>
</tr>
<tr>
<td>Pfänder</td>
<td>A14</td>
<td>6700</td>
<td>under construction</td>
</tr>
<tr>
<td>Bosruck</td>
<td>A09</td>
<td>5425</td>
<td>planning stage</td>
</tr>
<tr>
<td>Perjen</td>
<td>S16</td>
<td>2990</td>
<td>planning stage</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>54,849</strong></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1: Roadway tunnels on motorways and expressways with an added second tunnel tube

Furthermore, a main measure of the implementation work is the construction of emergency exits at a maximum distance of 500m, normally connected to an emergency tunnel. In the past many tunnels, especially bidirectional tunnels with a transverse ventilation system, have had no emergency exits.

As after more than 20 years, most electric equipment in the tunnel has normally reached its maximum functional lifespan, the corrective maintenance and upgrading to the technical-state-of-the-art of the first tunnel tube leads to significant extra costs in addition to the high costs for the construction of the second tunnel tube.
3. SAFETY DOCUMENTATION

The safety assessment of a road tunnel according to the Austrian law for tunnel safety is based specifically on the safety documentation of the tunnel in question. The requirements of the safety documentation are different depending on the respective project stage. In the design stage, the safety documentation focuses on the description of infrastructure and traffic, whereas during the operation stage the usage aspects gain importance. According to the state of ongoing project development, the information grows in detail. The safety documentation should be comprised of living documents which are continuously developed and upgraded, including changes in tunnel infrastructure and traffic data, as well as important findings based on experience.

Since then, safety documentation was prepared for each tunnel longer than 500m in the Austrian motorway network, which contains all safety-related information about the respective tunnel.

Recommendations for the content of safety documentation have been prepared by ILF Engineering Consultants (Linz) and consist of the following main topics:

- Introduction
- Description of the position of the tunnel in relation to the roadway network
- Description of the tunnel infrastructure and access to tunnel (lanes, cross sections, gradients, emergency exits, etc.)
- Description of the traffic situation, including the transport of dangerous goods and information on tunnel operation
- Specific hazard investigation: checking the safety parameters complying with the requirements of the Austrian law titled “Safety in Road Tunnels”
- Risk analysis according to the Austrian law titled “Safety in Road Tunnels” shall be carried out if the tunnel has special characteristics for defined safety parameters
- Description of additional measures or supplementary equipment, if they are necessary to ensure the level of tunnel safety
- Organisation of and resources for operation and maintenance
- Emergency response plan
- Feedback from experience, especially in the operational stage

The specific risk analysis is represented in the form of a table in which the singular points of the infrastructure-related measures according to the Road Tunnel Safety Law are listed. This table includes a column in which, using different colours, it is indicated whether the requirements of the respective criteria are fulfilled, not fulfilled or not applicable. If a safety parameter is not fulfilled, alternative measures must be proposed and evaluated. Additionally, it must be defined if these alternative measures are of preventive or damage limiting character and to what extent they contribute to risk minimization. Preventive alternative measures are for example increase of light intensity, reduction of maximum allowable speed and continuous observation of speed limit adherence. Damage limiting measures are the taking into account of the possibility of large fire loads, especially in case of higher large vehicle volumes as well as additional measures regarding the alarm and emergency plans.

Additionally the Austrian Road Tunnel Safety law requires an expert’s report regarding all safety parameters and all additional measures to ensure the compliance with the Austrian Road Tunnel Safety law incorporating the state-of-the-art of tunnel safety.
The experts should evaluate the plausibility and the interconnectedness of all safety relevant measures. In doing this, the specific risks of the respective tunnel must be demonstrated and discussed. According to law the safety officer must also prepare a statement regarding the safety of the tunnel in question, as he should know all details of and events occurring in the tunnel.

The safety standard for most Austrian tunnel structures is far higher than that required by the Road Tunnel Safety Law, as many details of tunnel design representing the technical-state-of-the-art are set by the Austrian Guidelines. As example one can refer to the high requirements for automatic processes as used for fire detection, ventilation control and emergency management, which significantly contribute to risk minimization in case of an incident.

4. RISK ANALYSIS

The EU Directive on road tunnel safety requires every member state to develop a method for a risk analysis at the national level. The tunnel risk model TuRisMo has already been completed in Austria and the description of this model, including some case studies, has been published in [1] of the Austrian Association for Research on Road-Rail-Transport. A report on the Austrian model has been presented at the 3rd Symposium in Graz from 15 - 17 May 2006.

The TuRisMo focuses on frequently occurring mechanical incidents and also fire incidents involving small and medium fires. The model can be used for a wide variety of different applications, such as safety assessment of new or existing tunnels, support of the decision-making process for selection of safety measures (new tunnels) or upgrading measures for existing tunnels, including the defining of priorities for upgrade measures, etc.

The risk analysis aims to investigate the risk for tunnel users (personal injury and fatalities). As a relevant reference value, the societal risk (fatalities per year) of the tunnel is calculated by combining incident frequencies and related values for defined scenarios in the event tree. The estimation of the probabilities in the event tree comes from statistical data, experience, the estimation of the related values on statistical data of mechanical incidents and simulations of fire scenarios.

The development of a risk assessment for the transport of dangerous goods is nearly complete. See section 5.

The EU Directive and the Austrian Road Tunnel Safety law allows limited exemptions for several requirements, on the condition that the same safety level can be gained via alternative risk reduction measures. For this reason, the Austrian TuRisMo provides a relative comparison of the risk of the tunnel investigated with the risk of a reference tunnel. A tunnel of the same length, type and traffic characteristic which fully complies with the minimum safety requirements per the “Austrian Road Tunnel Safety” regulation is used as a reference case. The mismatches identified can be assessed in terms of risk. Alternative measures to offset the exceptions can be evaluated; the risk reducing effects of the alternative safety measures can be investigated in a similar way. The assessment of safety measures can then be completed carrying out a cost-effectiveness analysis.

The method has been successfully applied for several tunnels in the Austrian motorway network having special characteristics.

On the basis of further tunnel incident data collection, evaluations of different scenarios can and will also be carried out in the future with regard to the event tree and damage extent analysis.
5. ASSESSMENT OF DANGEROUS GOODS TRANSPORT

With regard to the Road Tunnel Safety Law in Austria and the EC Directive 2004/54/EC, risks of the transport of dangerous goods (DG) in road tunnels are to be thoroughly examined within the scope of tunnel safety documentation.

In Austria these investigations have progressed quite far. Today experts are in the stage of detailed evaluation and are developing a multistage strategy to assess the risk of DG transport in roadway tunnels. These investigations are carried out using the DG QRAM model of OECD/PIARC.

Early in the investigations, it was necessary to gather very precise data about the amount and kind of the DG transported - hence elevations of DG transports were carried out in 12 areas from different main Austrian traffic routes. Summarizing all investigations of DG transports and analysing them according to ADR-classes, a subdivision was generated as shown in Fig. 2.

![Figure 2: Allocation danger good transports according to ADR-classes (AUT)](image)

Consequently, the allocation of investigated DG had to be assigned to the predefined accident scenarios (using the QRAM-model) based on hazard numbers, available lists or complementary searches of the specific material qualities (see Fig. 3).

![Figure 3: Allocation to the accident scenarios according to DG QRAM model](image)
With the evaluated data from each cross section a sensitivity investigation was carried out via application of DG-QRAM. A comparable reference tunnel (same direction traffic, length 1,500 m, 20,000 vehicles/day) was used to try to ascertain which DG distribution or which accident scenarios have the greatest influence on the result of the risk analysis (i.e. expected value). In addition it was checked as to whether a standardized DG distribution is applicable for a simple procedure for risk evaluation in Austria.

Today a whole strategy for risk evaluation of DG transports in roadway tunnels is in the final stages of preparation. As a first step in this strategy, a simplified assessment procedure had to be implemented. Thus a systematic calculation of the risks for specifically chosen reference tunnels began. In addition to the derivation of a standardized DG distribution for Austria, the different possible input data variants (tunnel length, ventilation system, kind and strength of traffic, share of large vehicles, etc.) were taken into account.

By determining agreed-on relevance criteria (e.g. expected value, F/N-curve) a first assessment can be made for any tunnel referring to the results of the systematic calculations for the investigated reference tunnels. If the defined flag criteria are met, more detailed investigations of the tunnel concerned must be undertaken.

The recent assessment strategy for a simple procedure to assess DG transport in road tunnels should be applied as a practical tool for use in reaching compliance with the EU Directive 2004/54/EC and the requirements given by the ADR.

6. COLLECTION AND ANALYSIS OF INCIDENTS

Collection and analysis of events are essential for the risk assessment of a tunnel and for the improvement of safety measures. Due to the great number of tunnels in Austria and the depth of accident data, the TiRisMo has been done based on Austrian data and experience. Data was collected from accidents involving personal injury in motorway and expressway tunnels for the years 1999–2003. The collection and analysis of incidents is now also completed for incidents occurring between 2004 and 2007. Relevant data for incidents in tunnels between 2004 and 2005 has been collected and an in-depth analysis has been carried out using police and court files. For the period from 2006 to 2007 data from the newly developed tunnel database has had to be corrected inserting official accident statistics.

The EU Directive requires reports on fires in tunnels and on accidents which clearly affect the safety of road users in tunnels, and on the frequency and causes of such incidents. For this reason, the Ministry of Transport, Innovation and Technology commissioned the Austrian Road Safety Board to develop a tunnel incident database. The ASFINAG provided the company server for this database and personnel for data entry in the tunnel control centers. The tunnel incident database contains data regarding tunnels on motorways and expressways as well as data for reportable events in tunnels. The data have been recorded since 1/1/2006 in the tunnel control centers, according to the requirements of the EU Directive and with respect to future research.

Accidents involving personal injury in tunnels are analysed according to point of origin, accident type and cause. The investigation by the Austrian Road Safety Board has shown that in tunnels with bi-directional and unidirectional traffic, the highest accident rate is in the portal area. In tunnels with bi-directional traffic, the accident rate in the areas just outside the entrance is higher than in the interior zone of the tunnel. For this reason, the new Austrian database includes the following detailed specification for incident locations:
- 7 -

- Area within 250 m outside the portal
- Entrance area (0m to 150m inside tunnel)
- Portal
- Interior zone (more than 150 m inside the tunnel)
- Area more than 250m outside the portal

Figure 4 shows the personal injury accident rate in the different zones outside and inside a tunnel.

![Figure 4: Personal injury accident rate [PIA/1 million vehicle-kilometres] in tunnels with bi-directional traffic and unidirectional traffic by point of origin of the accident (1999-2007)](image)

Accidents involving damage to property and without personal injury are also recorded in the new Austrian database because they have a high impact on road safety. The trends in future incident rates can only be analysed once data become available.

Over the last two years, a total of 130 accidents involving personal injury, 334 accidents involving damage to property and 16 fires occurred in Austrian tunnels on motorways and expressways. The highest share of all incidents in tunnels are accidents involving damage to property (69.7%), followed by 27.1% accidents involving personal injury. Fires are comparatively rare in tunnels.

7. CONCLUSIONS

The application of the Road Tunnel Safety Law allows onto compare the risks of different roadway tunnels in a new way. It is based on a safety report containing a description of all safety-relevant parameters as well as a risk analysis and evaluation. Hence, both all infrastructure-related and operation-related measures may be evaluated with regard to their risk minimizing effects and planned appropriately. This reviewing method is completely new with respect to the arrangements of safety equipment and may lead to a new methodology in this field. However, this is realizable only under the precondition that the risk-oriented evaluation, which contrasts with the current exclusively prescriptive view, is widely applied and accepted.

8. REFERENCES