Application of Risk Analysis for performance based Tunnel Design

Juergen KRIEGER
Director Divison Bridges and Structural Engineering
Federal Highway Research Institute (BASt), Bergisch Gladbach, Germany
Juergen.Krieger@bast.de

Juergen Krieger, born 1957, received his civil engineering degree from Technical University of Aachen

Frank HEIMBECHER
Head of Department Tunnel Construction, Tunnel Operation
Federal Highway Research Institute (BASt), Bergisch Gladbach, Germany
Heimbecher@bast.de

Frank Heimbecher, born 1969, received his civil engineering degree from the University of Bochum

Ingo KAUNDINYA
Civil Engineer, Department Tunnel Construction, Tunnel Operation
Federal Highway Research Institute (BASt), Bergisch Gladbach, Germany
Kaundinya@bast.de

Ingo Kaundinya, born 1974, received his civil engineering degree from the University of Bochum

Summary

The field of safety in road tunnels has always been an important issue for operators, owners and the responsible authorities. After the tunnel accidents in 1999 the subject gained however in importance. On European level the Directive 2004/54 EC on "Minimum Safety Requirements for Tunnels in the Trans European Road network" has been published. This guideline has to be implemented into national law by all Member States. According to this guideline all Member States of the European Community shall develop a methodology for risk analyses to be applied in certain cases. For Germany, a standardized methodology for a probabilistic quantitative risk assessment has been worked out.

Keywords: Road tunnel, Safety, Performance based design, Risk analysis, Tunnel safety

1. Introduction

The severe tunnel fires in 1999 in the road tunnels of Mont Blanc (F/I) and Tauern (A) pointed out, to which specific risks – mainly related to confinement – road tunnel users can be exposed in comparison to open roads. After the tunnel fires, guidelines and standards in the context of road tunnel safety equipment have been defined or upgraded in several European countries.

In April 2004 the Directive 2004/54/EC of the European Parliament and of the Council (EC Tunnel Directive) has been issued. This Directive has to be implemented into national law by each Member State. In Germany the implementation of the requirements of the EC Tunnel Directive has been done by updating the RABT to a new version, called RABT 2006. The EC Tunnel Directive implies certain requirements, for example requirements for the risk assessment for road tunnels, which are until now not implemented on national level. By using this approach tunnel design using a performance based approach is possible to a certain extent.

2. Road Tunnel Safety in Germany

In the past the selection of safety measures has been done on the basis of more or less prescriptive guidelines like RABT 2003 and other standards. The European Directive however, contains risk based approaches which can be applied in special cases and which are now also included in the current version of RABT. By using this approach the selection of safety measures can be done on the basis of performance based analyses to be applied in certain cases.

3. Risk Assessment for Road Tunnels in Germany

In order to fulfil the requirements of the Directive 2004/54/EC, a standardised methodology for a probabilistic risk assessment has been worked out. The methodology considers four types of scenar-

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ios break-downs, collisions, fires and accidents involving dangerous goods. Especially the scenarios for fires and collisions are in the focus of the methodology which is based on an event-tree-analysis. For gaining quantitative data a comprehensive analysis of accidents in German road tunnels was carried out for the assessment of the scenario frequencies.
For every tube of a road tunnel, the two following aspects of risk are analysed separately:

- Quantitative frequency analysis:
  - o Analytical approach for analysing the sequence of events from an initial event (accidents, breakdowns and fires) to a set of consequence scenarios.
  - o Statistical approach to quantify the initial events (rates of accident in tunnels) and the distribution (relative frequencies) to the branches of the event tree. Among other studies a comprehensive analysis of accidents in German road tunnels was carried out for the assessment of the scenario frequencies depending on risk relevant factors such as type of tunnel (unidirectional/bidirectional traffic), length, volume of traffic etc.
- Quantitative consequence analysis:
  - o Statistical approach to quantify the consequences of mechanical effects of collisions
  - o The consequences of tunnel fires (5 MW / 30 MW / 50 MW / 100 MW) are assessed by using specific models in order to simulate smoke spread and the effect of the tunnel ventilation. In addition a pragmatic method to assess evacuation is proposed (including the location of the accident, the location of the emergency exits, the spread of smoke and the resulting visibility, the constellation of the vehicles on both sides of the accident etc.).

The resulting calculated risk for all tubes of a tunnel can be graphed as FN curve or expressed as expected value of the societal risk. In addition the results can also be expressed in terms of the perceived societal risk. It is a fact that rare events with very high consequences are perceived much more in the public than frequent events with low consequences. Therefore governmental administrators or safety officers responsible for the safety of a third party have an additional concern to avoid catastrophic events. Such accidents may lead to additional safety precautions. The public perception of rare events with high consequences is disproportionate to the loss expectancy. In order to transform the societal risk into the perceived societal risk a consequence-dependent risk aversion is introduced.

At the time being, risk evaluation is done by relative comparison, mainly by comparing the tunnel as it is to the situation as it should be, taking the requirements of the RABT 2006 into account. For the planning of safety measures a methodical approach to take into account the aspects of cost-effectiveness is part of the proposed method for risk analysis for road tunnels. This approach allows a comparison the effect of additional safety measures in terms of risk reduction with the required costs for implementation and operation. Thus, the methodology can be used as a performance based design tool for new tunnels as well as for upgrading existing tunnels.

4. Conclusions

The process of a risk-based road tunnel safety management allows a structured, harmonised and transparent assessment of risks for a specific tunnel including the consideration of the relevant influence factors. Moreover, it allows coming up with the best additional safety measures in terms of risk mitigation and enables a comparison of different alternatives in the context of a performance based design approach. Among other risk relevant factors of influence the German methodology allows the assessment of risks for a specific tunnel considering the influence of different safety measures as required in RABT 2006 and the Directive 2004/54/EC. Hence, the influence of alternative measures can be assessed too. Thus, the methodology can be used for a performance based decision support in the context of providing safety measures when designing new or upgrading existing tunnels.