



## Structural retrofitting of older German road tunnels – Possibilities to fulfil current requirements regarding structural fire protection

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### Summary

This paper deals with possibilities to update existing road tunnels in order to fulfill up to date requirements regarding structural fire protection. Besides the upgrading of tunnels with structural fire protection systems (like e.g. fire protection sheets) there is also the possibility of numerical investigations. In research projects carried out on behalf of the Federal Highway Research Institute (BAST) numerical investigations for the proof of sufficient structural fire protection have been done for common road tunnel types. Additionally the influence of different fire loads and fire durations on the bearing capacity of the structures have been investigated. The results of these research projects have been used to define a procedure how to investigate existing tunnels regarding structural fire protection. The research results have also been the basis for a current update of national standards for tunnel construction.

**Keywords:** road tunnel; retrofitting; structural fire protection, fire curve.

### 1. Introduction

Tunnels are important elements of the German federal road network which have to cope with an increasing traffic load especially of heavy goods vehicles. In order to ensure a high availability and safety level for these key infrastructures big efforts are required by owners and operators in order to keep all infrastructures up to date. This mainly relates to current European regulations regarding tunnel safety (Directive 2004/54/EG) and their national implementation which must be fulfilled by many existing tunnels. In this context the German Federal Government spends nearly 1 billion € for the structural and operational retrofitting of more than 120 existing road tunnels. As many of these projects have recently been finished or are still under progress experiences and best practices could be reported.

### 2. Requirements regarding structural fire protection

The structural fire protection design of road tunnels is usually based on temperature-time curves of exposure to fire, for simplicity called "fire curves". In German road tunnels, the structural fire protection is targeted at maintaining structural integrity and serviceability of the structure. By complying with the requirements defined in the "Additional technical terms of contract and guidelines for civil engineering works (ZTV-ING) Part 5 "Tunnelling", it is ensured that the tunnel can withstand the effects of fire and, after an incident, can be put back in operation at a reasonable cost. The fire curve applicable for German road tunnels is the so called ZTV-ING curve (Fig. 1).

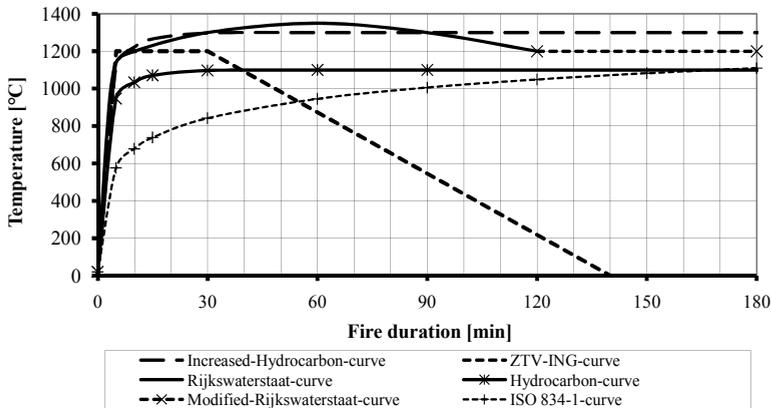


Fig. 1: International fire curves for structural fire protection of road tunnels

### 3. Procedure regarding upgrade of structural fire protection

Due to the big efforts and high costs for the upgrading of tunnels with structural fire protection systems the German Federal Ministry of Transport (BMVBS) together with the Federal Highway Research Institute (BAST) has defined a procedure, how to investigate older road tunnels regarding structural fire protection if a no sufficient concrete cover of the reinforcement has been discovered:

1. Detailed recording of the actual concrete cover
2. Examination of the geological boundary conditions assumed during tunnel design and construction
3. Numerical investigation of the bearing capacity under fire load considering the geological boundary condition, the existing structure with its actual concrete cover and geometry, etc. Demand: The stability of the whole tunnel structure must be ensured for all cases at any time (i.e. during and after fire exposure)!
4. If the numerical verification of the tunnel structure under fire load fails, additional fire protection measures (e.g. fire protection sheets or render) must be designed and investigated by an expert/consultant.

### 4. Conclusions

The upgrading of tunnels with structural fire protection systems (like e.g. fire protection sheets) is only one possibility to fulfil current requirements regarding structural fire protection laid down in the respective guidelines and standards. Another possibility are numerical investigations of the tunnel structure under fire load. The numerical analyses carried out in a BAST research project have shown, that common road tunnel cross-sections can also withstand higher fire impacts than indicated in the national fire curve, provided that no major concrete spalling occurs. The preferred procedure when dealing with structural retrofitting of older road tunnels in Germany is first to try to proof sufficient fire resistance of older tunnels by numerical investigations. If this proof is not successful additional structural fire protection measures (e.g. fire protection sheets or render) must be designed and installed.