



Performance-based design of road tunnel fire safety: Proposal of new Swedish framework



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ABSTRACT

This paper contains a proposal of new Swedish framework for performance-based design of road tunnel fire safety derived from Swedish and European regulation. The overall purpose of the guideline is to protect life, health, property, environment, and key societal functions from fire. The guideline is structured into five key groups of requirements: #1 Proper management and organisation, #2 to limit the generation and spread of fire and smoke, #3 to provide means for safe self-evacuation, #4 to provide means and safety for the rescue service, and #5 to ensure load-bearing capacity of the construction. Each group contains a hybrid of prescriptive requirements, performance-based requirements, and acceptable solutions. Prescriptive requirements must be fulfilled, however, it is the choice of the design team to either adopt the proposed acceptable solutions, or to design alternative solutions by verifying that performance-based requirements are satisfied. For verification of performance-based requirements through risk analysis the operational, epistemic, and aleatory uncertainties are considerable. Therefore, a scenario-based risk analysis with several specified input variables and methods is recommended for verification of #3 and #5. Indispensable complements are scenario exercises, emergency exercises and similar methods that validate the design and highlight organisational aspects. The proposed design guide has been developed by the authors together with the advisory group established for the work.

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Introduction

Catastrophic tunnel fires such as the Mont Blanc fire in 1999 have highlighted the potential consequences of such events. In the Mont Blanc case many people lost their lives, and the tunnel remained closed for several years [1]. In 2004 The European commission issued a directive on minimum safety requirements for tunnels in the trans-European road network [2].

Despite the directive and several national laws on tunnel safety, at large there is a lack of agreement regarding what constitutes tunnel safety and how verification of safety should be performed. Swedish stakeholders have a diversified view on this subject, it is to some degree unclear what constitutes fire safety, what an acceptable fire safety level should be and which roles different stakeholders have [3,4].

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According to the EC directive a risk analysis has to be performed, but it is not clear why or how the results should be used. In practice, due to several prescriptive requirements, there is a limited possibility for safety trade-offs. Furthermore, there is an imbalance, as most measures focus on reducing consequences instead of reducing the likelihood of occurrence. This is often due to predefined design fire requirements in which the fire has already been assumed to have happened, i.e. likelihood of occurrence is not emphasized. It was realised that future research should focus on developing the concept of acceptable performance and risk if we are to be able to consider safety trade-offs [4]. Therefore a project was initiated by the Swedish Transport Administration (STA) with the goal to develop performance-based fire safety guidelines. The purpose of this paper is to present a concept for more performance-based guidelines which would allow for risk-based design and for safety trade-offs, e.g., technical trade-offs between fire suppression and fire resistance.

The general idea of the new tunnel guideline was to resemble the procedure from the building regulation. By doing so it is hoped that the building industry will be familiar with the structure and procedure.

Legal requirements and political objectives

Several legal requirements and political objectives influence how a tunnel is designed and therefore also what requirements the tunnel must fulfil. The overall requirement for Swedish road infrastructure is to ensure a socio-economic efficient and sustainable provision of transport for citizens and industry throughout the country. Keywords are availability, safety, environment and health [5]. On a legal level the planning and building act [6] and the planning and building ordinance [7] applies to tunnels as they are construction works. In this ordinance five basic fire safety requirements for structures can be identified from the EU Construction Products Directive (CPD). For tunnels the act on safety in road tunnels [8] and the ordinance on safety in road tunnels [9] further specify the requirements set out in the EC directive. Other laws concerning crisis management [10,11], fire safety management [12,13], and the prevention of accidents [14] also sets requirements for the performance of tunnel fire safety. Specific requirements for buildings are issued by the Swedish National Board of Housing [15].

The Swedish building code

The current building code is, compared to previous editions, updated and re-written to better provide the designer with performance-based regulations and general recommendations supporting the requirements. As not all requirements can be formulated in a performance-based manner some prescriptive requirements still exist. The code separates the requirements from the recommendations which in turn provide guidelines for how the requirements can be fulfilled. The level of safety is then defined by the use of the general recommendations but they are not mandatory and other solutions to the requirements may be obtained by performance-based methods which fulfils the requirements, but not the general recommendations. The designer has to follow all prescriptive requirements.

The Swedish National Board of Housing, Building and planning [16] also issued guidelines for the verification method for performance-based solutions (known as the analytical design option). This guideline provides the designer with a recommended procedure for how to verify that the building meets the requirements. The guideline also includes information on practical design issues. The most frequently used formal base for the verification is the scenario-based risk analysis. The designer can apply other higher order methods like a quantitative risk analysis but also more qualitative methods. However, for these latter methods there are no detailed recommendations presented apart from the general procedures on performance-based design.

The performance-based procedure in the guideline presents a four step approach that has to be followed.

- Identification of the verification needs.
- Verification of a sufficient fire safety level.
- Review of the verification.
- Documentation of the fire safety measures in the building (including the performed control).

An important part of the procedure is the first two steps. The first step is used to identify the boundary conditions for the analysis and dependencies within the fire safety system. The second step includes a risk identification task aiming at identifying potential scenarios that are relevant for further analysis. There are no explicitly given scenario locations for each building type but the risk identification is supposed to provide the designer with a proper baseline for the ensuing verifications.

Theoretical framework for safe design

Performance-based design has become more common in several areas, for example within the building industry. In order to implement performance-based requirements for tunnels, functional requirements must be specified specifying the function and purpose of the tunnel from a fire safety perspective.

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