Emission and smoke recirculation in road tunnels (FGU2008/007_OBF)

Schadstoff- und Rauchkurzschlüsse bei Strassentunnel

**Funding:** National (Switzerland)
**Duration:** Jun 2009 - Nov 2013
**Status:** Complete with results

**Background & policy context:**

To quantify emission and smoke recirculation in road tunnels very few established guidelines are available. Nowadays arrangements to reduce recirculation are decided upon rudimentarily specifications and knowledge.

The planned research work aims to extensively investigate recirculation in road tunnels. The results should be used in the future as a basis for the design of new and existing tunnel ventilation systems (new guidelines).

The main part of the research covers a systematic analysis of the factors of influence regarding recirculation (e.g. jet velocity, height of the chimney, portal situation, wind) using CFD-Simulations. The simulations will be validated with in situ measurements on existing road tunnels. The measurements will be carried out using the well-proven tracer gas method by an accredited laboratory. On the basis of the simulation and measurement results, a method to quantify will be developed. A further part is to define appropriate requirements and recommendations as well as documentation.

**Objectives:**

The principal objective of the research is to create a comprehensive basis for a better understanding of emissions and smoke recirculation in road tunnels with and without ventilation systems. The primary aim of the research would be:

- Evaluation of the risk potential (in what way is recirculation a problem, what are the hazards?)
- Creation of fundamental knowledge regarding emission and smoke recirculation
- Development of a method to evaluate emission and smoke recirculation and arrangements for new and existing road tunnels. The method considers all the relevant aspects, such as height of the chimney, jet velocity, etc.
- Definition of recommendations, requirements and possibilities to compensate (What are the requirements? How much recirculation is allowed? What are the arrangements to achieve the requirements?)
- Publication of the results on national or international environment (journals, conferences).

The research project aims primary to eliminate the uncertain, inaccurate or missing basis in the field of emission and smoke recirculation. That can result in considerable cost and time savings during the design and realisation.

**Methodology:**

The following stages are planned for the project:

**Part 1: Development of the foundations / hazard potential**

The first part is on the one hand a literature review on the other hand a theoretical and practical considerations of circulation bypasses of existing tunnels.

The literature already available development / research approaches used (eg. guidelines) to be collected, analysed and assessed and common practice. Based on theoretical and practical considerations to flow short circuits and related aspects (eg. structural measures, methods) to analyse and describe.
The potential risk for tunnel users, emanating from short circuits of smoke or pollutants should be examined by a risk analysis.

Part 2: Parameters of the recirculation

The second part comprises primarily the detailed analysis of the various influencing factors regarding the smoke and pollutants shorts. The various influencing factors (chimney height, distance Fireplace - Portal, blow-off, wind conditions, site situation, etc.) are examined systematically using detailed CFD simulations. The simulations should show relevant factors that must be considered in the design of tunnel ventilation. In addition to the factors influencing new tunnels should be identified on the basis of simulations additional opportunities that can improve the safety situation as regards the recirculation of tunnel users in existing tunnels without major structural measures. This can be, for example, the incorporation of diaphragms for increasing the blow-off speed or a suitable ventilation control.

The CFD simulations provide various parameters by which the recirculation of smoke and pollutants can be influenced and their dependence on one another. The factors are based on various criteria (new tunnel system - rehabilitation of existing plant, necessary structural adjustments, non-controllable environmental factors, etc.). The aim is an approach to avoid flow short circuits are achieved.

Part 3: Validation and Review

Some of the performed CFD simulations are to be validated by measuring the flow shorts to existing tunnels. The measurements are performed using proven Tracer gas method.

Part 4: Definition of guidelines / recommendations

The CFD simulations and validation by measurements intended to provide a guide and a procedure for the design of new and existing tunnels. The influencing parameters should be defined and classified according to the

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**Key Results:**

Evaluation of the harm potential

A method has been developed to assess the threat to the users of the tunnels by smoke recirculation. It answers the question “How much smoke recirculation is acceptable?” It assumes the analogy of pool fires and vehicle fires and relies on the theory of pool fires, the experimental results of the combustion of pure fuels and vehicles, the theory of light extinction in smoke and the empirical relation between visibility, extinction and the sensory aptitude of people in a smoke filled environment. This method is applicable to both the portal to portal and the stack to portal recirculation. It unifies all three aspects of recirculation – emission, transmission and nuisance – in one diagram. This diagram presents the functional dependence of the critical recirculation rate from the fire power in the incident tube and the visibility in the tube filled by recirculating smoke. It is used to assess the results of the CFD-studies.

**Portal to portal recirculation**

The recirculation between portals has been examined numerically in a parametric study. The parameters varied were the staggering of the portals, the length of the separation wall, the wind velocity and the wind direction. The atmosphere was assumed neutral and isothermal, the earth boundary layer logarithmic and the surrounding terrain as open country with low scrub and scattered trees. The results are valid for the recirculation of smoke and pollutants in modelled geometric and atmospheric limits. They are therefore not valid for a tunnel in a trench or a street canyon. They are also not valid for flows leaving the portals hotter than the environment, and for unstable atmosphere.

The recirculation rates found lie between 0 and 55 %. The driving force of the recirculation is the wind velocity and direction: The recirculation is highest at cross wind and increases then with wind velocity. A separation wall of at least 30 m has shown to be an effective measure against recirculation in this case. If the wind is directed against the portal, the recirculation at low wind velocity is always higher than at the same wind velocity and cross wind. The buoyancy of hot tunnel air has a positive reducing effect on recirculation when the temperature difference to the environment is high. A statement for low temperature differences is not possible to the present state of knowledge.

The recirculation rates found are generally critical for low and medium fire powers according to the h

Documents:

- FGU2008-007OBF.pdf (Final report)

**STRIA Roadmaps:** Other specified

**Transport mode:** Road transport

**Transport sectors:** Passenger transport, Freight transport

**Geo-spatial type:** Other