DETECTION, VENTILATION- AND WATER MIST SYSTEMS AS ACTIVE FIRE PROTECTION FOR TUNNELS

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Abstract: **this paper tries to develop a method to calculate the optimum operating conditions for an integrated 'Tunnel Safety System' consisting of a ventilation- and water mist system both activated by a detection system.**

Keywords: **Tunnel, design fire, backlayering, watermist nozzle, fiber optic heat detection.**

I. INTRODUCTION

Underground transport facilities (road, rail, metro) in Europe are sensitive links in the economic chain that carry millions of people and tons of goods every day and they are growing in importance. Therefore a breakdown in operations can have catastrophic consequences. That is why safety precautions are vitally important By far the greatest risk is a fire of a heavy good vehicle which can be a threat for the passengers life caused by toxic combustion gases, exceedingly high temperatures, total loss of visibility and the panic reactions of drivers and passengers. The emergency services are usually hindered by the smoke and gas generated by the fire which at the same time causes serious damage to the infrastructure of the transport facility.

The dramatic events in the Mont Blanc and Tauern tunnels triggered a wide public debate on the safety of road and rail tunnels leading to demands for comprehensive safety precautions to safeguard the survival of travellers, to keep damage to the facility to a minimum and to maintain its availability.

Results of full-scale tests in the Runehamar tunnel, of Heavy Goods Vehicle (HGV) loads, are used to asses theoretical calculations form the author in every section of the paper.

II. RISK ANALYSIS & DESIGN FIRES

Fire risk can be represented as "*Fire Risk = Probability x Consequence*" where the probability component is the likelihood of various causes of fire and the consequences component is obtained from the fire growth characteristics such as the combustible material (technical systems, vehicles and their goods) and conditions (ventilation speed humidity) in the tunnel .

The paper describes a methodology to indentify the worst case fire design scenario using logical tree structures in which the causes are determined by a "fault tree" and the consequences by using an "event tree" .

The output are a numerous numbers of fire scenarios of which the worst case will be used to quantify the "design fire" in order to design the detection-, smoke and water mist systems.

When designing tunnels, there is no opportunity to calculate and analyse the individual heat evolving. Instead of describing of fires in terms of a "correct" standard fire, characteristic curves were established to describe the characteristic of an average tunnel fire. The common used fire-characteristic curves are shown on (FIG. 1)

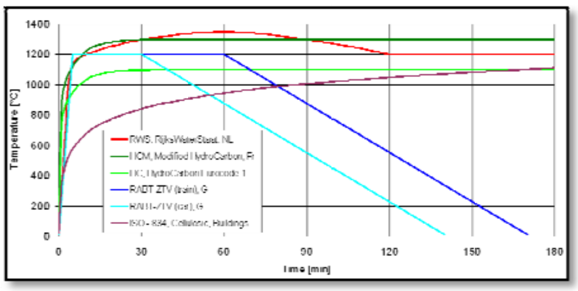

FIG. 1: COMMON USED FIRE-CHARACTERISTIC CURVES

This paper contains an overview of peak HRRs and temperatures of four large-scale tests (T1-T4) in a mock-up of a Heavy Goods Vehicle (HGV) trailer in the Runehamar tunnel.

Those results proves that real fires not always follow the standard characteristic fire curves.

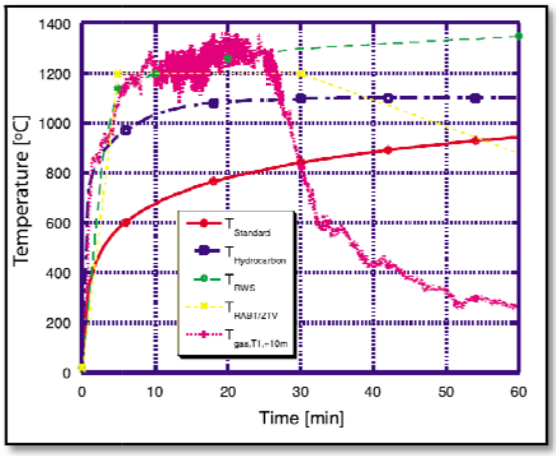

FIG. 2: STANDARD CURVES <-> REAL FIRE CURVE

Various ways exist to represent real design fire curve for tunnels. These can include different fire growth rates or combinations of fire growth rates (e.g. linear, quadratic etc)with constant levels of heat release rate (HRR) coupled to a decay period. This means that the curve has to be represented with different mathematical expressions for different time periods. A more convenient way is to describe the design fire curve with a single mathematical expression (H. Ingason).

III. VENTILATION SYSTEMS

Creating a smoke free path for evacuation and facilitating fire fighters to access the fire is critical for fire and rescue operations. A means of achieving this is to use ventilation fans to blow sufficient air down the tunnel ensuring no back-layering of smoke occurs upstream of the fire.

The airflow necessary for such operation is known as the critical velocity. The critical velocity is a function of a number of factors which includes the heat release rate, tunnel gradient and tunnel geometry. Calculations are made to determine the maximum HRR that a ventilation system can handle with respect to the maximum allowed smoke temperature and acceptable airflow speed.

Existing experimental tunnel fire data have been analysed to identify trends in the variation of fire growth rate at different longitudinal ventilation velocities and different positions of the fire ignition.

IV. WATER MIST SYSTEMS

The core of water mist systems is the nozzle, which does the atomization of water to small droplets. The most often used atomization mechanisms are jetting and swirling flow nozzles. This paper presents the principles of high-pressure water mist fire fighting, focusing to the nozzle design.

The length of the water mist zones is assessed by studying the influence of the ventilation on the droplets behavior by a simplified method calculating the horizontal traject of different sized droplets at different ventilation speeds.

Calculations are made to determine the maximum HRR that a water mist system combined with a ventilation system can handle. The outcome of these calculations is that fully developed fires (e.g. in the range of 200 MW) can never been controlled by those systems. By means of early detection and activation it is possible to control those fires (with a potential fire load of 200MW) in an early stage of their development.

V. DETECTION SYSTEMS

The automatic fire detection in a road tunnel with the possibility to trigger automatically measures and interactions is crucial in the protection concept. The most important detection technologies are explained and their assessment for the requirements are evaluated. The performance requirements for tunnel fire detection systems are described in order to give the reader an evaluation guide.

It’s being recognised that a linear heat detection using fibre optic cables and laser technology provides a reliable detection technology especially for tunnels. Often modern traffic control systems equipped with

CCTV cameras together with smoke and exhaust gas measurement are there to help recognising and localising a fire accident in combination with a fire detection system. These detection devices give designers tools to design or re-design the systems dimensioning in terms of zone sizing.

VI. CONCLUDING THOUGHTS

A protection concept for road tunnels shall consist of the following points:

• Structural and organizational measures: escape tunnels, escape areas, rapid smoke extraction, rescue procedures.

• Accurate and timely fire location that is not averted by strong air currents.

• Automatic triggering of interactions to control traffic, to assess the risk at the site of the fire, to control ventilation and alarm the emergency services.

• Automatic control of extinguishing systems to hold down the fire and control the temperature until the emergency services can be deployed.

The three elements studied in this paper must be designed to work together as part of an integrated 'Tunnel Safety System' rather than being dimensioned as individual systems.

The optimum operating conditions for our integrated 'Tunnel Safety System' is more important than the individual performance of the systems.

Achieving seamless interaction with these systems, delivered by different system providers and having different operational priorities is one of the greatest tunnel fire protection challenge