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Thesis

A Study of the Heat Release Rate of Tunnel Fires and the Interaction between Suppression and Longitudinal Air Flows in Tunnels

Abstract

An experimental study addressing important tunnel fire safety issues has been conducted in a full-scale laboratory tunnel at Carleton University. The study developed a Heat Release Rate (HRR) measurement system that will be used for tunnel fire research. Also, the study investigated the effectiveness of Water-based Fixed Fire Fighting Systems (WFFFS) together with longitudinal ventilation systems in mitigating the effects of fires in tunnels.

First, a HRR measurement system was developed in the full scale laboratory tunnel. The system uses oxygen consumption calorimetry for reliable measurements under various ventilation conditions, as well as with a suppression system operating. The HRR measurement system measures mass flow rates and CO2, CO and O2 concentrations of the exhaust gas in a large-scale exhaust chamber that is designed to collect all combustion products from the tunnel. The instrumentation design for the HRR measurement system required an extensive analysis of the flow patterns in the exhaust fan chamber due to its large scale. This study identified the optimum amount of instrumentation and its optimum location to ensure reasonable accuracy. A series of calibration tests was conducted to evaluate the accuracy of the system for various fire sizes under different ventilation conditions. Based on the calibration test data, it was found that for unsuppressed fires the relative combined uncertainty of the system is about 10-15%. The impact of water vapour introduced by the suppression system on the system accuracy was also investigated. A simple method was proposed to correct the HRR measured during suppression.

Secondly, this study examined the strategy of using both a longitudinal ventilation system and WFFFS. Test results showed that this strategy effectively controls smoke and successfully resists backlayering with a reduced longitudinal air velocity. The present study established a method to estimate the degree of backlayering that considers the fire size, longitudinal air velocity and water spray density. Ceiling temperature profiles along the length of the tunnel were also examined, and a method to estimate the maximum ceiling temperature is proposed. The method can estimate the cooling effect of the WFFFS along with the longitudinal ventilation system on the maximum temperature that the tunnel ceiling experiences. The study also examined the radiation attenuation by the WFFFS. Results showed that the radiation attenuation was significant particularly in the area downstream of the fire.

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Supervisor

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