Experimental and numerical study of water mist and smoke control system interaction on building evacuation routes

Grzegorz Krajewski[1], Jakub Bielawski[1,3], Bogdan Racięga[2] Wojciech Węgrzyński[1]

[1]Building Research Institute, Poland, g.krajewski@itb.pl, j.bielawski@itb.pl, w.wegrzynski@itb.pl

[2]Baltic Fire Laboratory, Poland, bogdan.raciega@bafilab.com

[3]Hong Kong Polytechnic University, China

Grzegorz Krajewski

Jakub Bielawski

BIO Grzegorz Krajewski:

Grzegorz Krajewski graduated from the Warsaw University of Technology, majoring in HVAC and fire safety at the Main School of Fire Service. He defended doctoral thesis on topic related to full-scale research coupled with numerical analyzes of the spread of smoke and heat. He is the author and co-author of a number of articles related to environmental parameters during a fire and wind engineering. On a daily basis, he works at the Fire Research Department of the ITB, where he takes an active part in the development of guidelines and expert opinions based on numerical analyses and in the process of preparing and accepting building structures for use. Currently, his research is focused on full-scale research on environmental conditions on horizontal escape routes depending on internal and external factors, such as the type of ventilation, fire extinguishing systems and the influence of the wind.

BIO Jakub Bielawski:

Jakub Bielawski is a research assistant at the Building Research Institute in Poland and a visiting PhD student at Hong Kong Polytechnic University. His PhD research focuses on performance-based adaptation of fire safety systems in terms of actual conditions airflow, fire behavior, and smoke flow. In his research, he combines experimental and numerical methods with novel analysis methods such as machine learning algorithms. Jakub is part of the team of the Building Research Institute for the commissioning of fire safety systems of actual tunnels in Poland. He performed more than 150 hot smoke tests in tunnels and buildings. He also participates in research projects in the field of fire safety of building facades, green walls, and timber structures and aerodynamic tests in wind tunnel.

Background

The fire safety strategy for buildings is based on ensuring safe conditions for the evacuation of people. This is reflected in codes and standards as Available Safe Egress Time (ASET) and Required Safe Egress Time (RSET). The assumption of fire engineering is to provide RSET<ASET using a technical solution. These include smoke extraction systems and fixed firefighting systems (FFFS). Each of these systems has different characteristics and design goals. In modern buildings, where the highest level of fire safety is required, these systems are often used in conjunction. However, precise criteria for the interaction of both systems have not been developed so far. This requires taking into account the airflow velocity, operational pressure of sprinklers/water mist, and their impact on critical environmental conditions that interrupt safe evacuation, such as gas temperature, heat flux, and visibility.

Objectives

The main objective of the study is develop an engineering basis for the interaction between water mist and smoke control systems to improve fire safety in buildings. Various types of smoke exhaust systems will perform differently with water mist in terms of forced flows and droplets entrainments. Crucial is to find the optimal parameters of both systems for improving fire safety in buildings.

Methodology

The experimental part of the research was carried out in a full-size facility consisting of a 30 m long corridor connected by 3 individual compartments. The corridor is equipped with inlet and outlet vents of the smoke exhaust system and a hydraulic installation for water mist nozzles supplied by a pump. The variables in the study were Heat Release Rate (HRR), types of smoke exhaust system and types of FFFS. The fire source was a gas burner, and the HRR was in the range of 0.2 - 2 MW. It was performed tests for 2 types of smoke control systems: transverse and longitudinal at different system capacities and 3 types of FFFS: low-pressure water mist (LPWM) and high-pressure water mist (HPWM) and their comparison to conventional sprinklers. Water mist nozzles and sprinkler heads were mounted in the same locations in each series of tests for comparison of impact.

Fire scenarios were modelled using CFD code Fire Dynamics Simulator. This CFD code is dedicated for fire scenarios with buoyancy-driven flows with emphasis on smoke and heat transport. The geometry of the corridor was built and discretized in cartesian coordinates for a finite number of control elements. Water mist action was modelled as injection of discrete particles using Lagrangian formulation.

Results and conclusions

The study is extensive and a series of tests are underway. Preliminary conclusions have been drawn from the research results so far. There is a clear interaction between the ventilation system used and the water installation system. Depending on the type of ventilation used (longitudinal or transverse), significant differences in the temperature profile across the corridor can be observed. Due to the location of the water mist and sprinkler heads in near the extraction point, a partial decrease in the efficiency of the water installation is visible. The final presentation paper will consist of quantitative results of the tests and numerical simulations.

KEYWORDS: low-pressure water mist, high-pressure water mist, sprinklers, smoke control system, CFD modelling, building evacuation routes