Experimental and numerical investigations for the prediction of depth of calcination of gypsum plasterboards under fire exposure

Project Abstract

The goal of the proposed research is to develop a reliable predictive tool for the analysis of gypsum calcination. Gypsum plasterboards are commonly used in building construction due to their fire-resistant properties. Gypsum undergoes calcination when exposed to fire. This leaves fire patterns on the gypsum board and most forensic fire investigations rely on it. A one-dimensional unsteady computational model has been developed to solve the mass, species, momentum, and energy conservation equations inside the porous gypsum board to predict gypsum calcination under fire exposure based on a simplified gypsum dehydration model. The proposed study will conduct Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC), and Fourier-Transform Infrared Spectroscopy (FTIR) to characterize the calcination of gypsum boards from different manufacturers. This will lead to a reliable gypsum thermos-chemistry model which will help to explore the phenomenon of gypsum calcination and systematically analyze fire patterns. The endothermic dehydration of chemically bound water in calcium sulfate dihydrate, variable thermo-physical properties, re-condensation of the water vapor, and the heat and mass transfer through the porous material will be considered. The numerical predictions from the one-dimensional model will be validated by comparing the predictions with the experimental measurements with controlled uniform heat flux, surface temperature, and duration of exposure. Repeatable and reproducible experiments with a wide range of heat flux, surface temperatures, and duration of exposure and the depth of calcination will be measured. After the chemistry model is validated, a three-dimensional computational model will be developed that can predict the gypsum calcination under non-uniform heat fluxes and temperatures from the fire. The model will consider species transport in all three directions due to both local pressure gradients and concentration gradients. The predicted depth of calcination and the temperature field inside the gypsum board will be validated against controlled experiments with pre-decided spatial gradients in heat flux in each direction. The numerical predictions will also be compared to the full-scale compartment fire experiments available in the literature. TGA and FTIR will be used to characterize the gypsum boards after fire exposure to correlate the depth of calcination with the degree of dehydration. Simplified correlations between the depth of calcination, heat flux from fire, and duration of exposure will be developed based on the numerical predictions and will be tested experimentally. A user-friendly executable will be developed that will help fire investigators predict the depth of calcination based on the known history of fire spread or the model outputs of wall heat flux or temperature from computational tools like Fire Dynamics Simulator.