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Review and validation of the current smoke plume entrainment models for large-volume buildings

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Abstract— The design of smoke management systems in large-volume enclosures is of utter importance for life safety, property protection, and business continuity in case of fire. Despite the recent international trend in smoke control design towards the use of advanced fire models, simple plume entrainment correlations are the basis of the discipline and are still a common practice since they are often incorporated in technical documents for the design of smoke control systems. Different plume entrainment correlations have been developed over the years and are cited in different national codes and design guides. These correlations have been widely investigated for fires in small enclosures, but their applicability and accuracy in large enclosures is not clear. The present work studies the suitability and applicability of these approaches to properly predict the fire induced conditions within large volumes. The results obtained from the plume entrainment correlations have been compared with full scale experimental data in an 8.000 m3 enclosure. Based on the results obtained by this analysis performed in a large-volume enclosure, the current methods available of modelling fire and determining the smoke produced by the fire might not be suitable. It was observed that for the steady state, the McCaffrey correlation gave results closest to the experiments, and for the transient evolution of the smoke layer, the Zukoski correlation. On the contrary, the popular Thomas method underpredicted smoke production and entrainment, giving the highest smoke layer interface heights and leading to estimations that are not conservative (with errors between 36.5% and 101%). The authors analyze the reasons for the discrepancies and give some practical recommendations for the design of smoke control in large volume buildings, such as that the use of such models to predict the smoke production of a given fire shall be only a first approximation and not a design tool, especially when using those models that have not shown a good match to the experimental data.

Index Terms— Smoke control; Smoke management; Smoke dynamics; Plume entrainment correlations; Large volumes; Plume models; Large scale tests; Zone modelling

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