Demonstrating Performance-Based Fire Design of Composite Buildings

Thomas GERNAY

Assistant Professor

Johns Hopkins University

Baltimore, MD, U.S.A.
tgernay@jhu.edu

Dr. Gernay holds a PhD from ULiege and was a Fulbright scholar at Princeton University. He specializes in computational modeling of structures in fire.

Negar E. KHORASANI

Assistant Professor

University at Buffalo

Buffalo, NY, U.S.A.

negarkho@buffalo.edu

Dr. Elhami Khorasani holds a PhD from Princeton University. Her research focuses on fire engineering and community resilience.

Contact: tgernay@jhu.edu

1 Abstract

Performance-Based Fire Engineering (PBFE) is gaining traction in the US, with the aim to provide safe, resilient and cost-effective design solutions for structural systems in our evolving communities. Steel-framed buildings with composite steel-concrete floors are widely used in practice and offer opportunities for achieving robust fire performance through PBFE. This paper demonstrates the design process, computational modeling approaches, and main assumptions for PBFE of steel-concrete composite buildings using a streamlined and systematic methodology. Performance expectations are explicitly spelled out at the outset of the process. A set of design fires are generated using zone models based on high percentiles of the fuel load. Then, the thermal-structural response is modeled using nonlinear finite element analyses. Design alternatives are evaluated against the predefined performance expectations. While the prescriptive code design does not survive until burnout, PBFE alternatives can survive the fire, adopting selected structural upgrades and an optimized allocation of the thermal insulation on the steel members. The activation of tensile membrane action in the fire-exposed composite floor is captured by the model. Single bay models are compared to full building models, showing the beneficial contribution of the system restraints provided steel mesh continuity is ensured over the girders. Thus, the single slab model provides conservative results at lesser computational cost. The full building model allows investigating robustness under extreme scenarios such as multi-compartment fires or multi-hazard scenarios with fire following a column loss. Adoption of this design process by structural fire engineers can lead to robust PBFE designs with explicit evaluation of the response under a range of extreme events, for a demonstrated performance level that is pre-agreed between the stakeholders.

Keywords: fire; structure; performance-based design; numerical model; composite buildings.

2 Introduction

The fire safety of building structures has long been handled by engineers or architects through implicit, prescriptive methods which do not require an assessment of the expected structural response under fire. Recently, the benefits of adopting a more scientific-based approach in which the performance expectations for the structure in case of fire are explicitly spelled out and the expected response is evaluated by calculations, have started to be recognized. While the shift from a prescriptive to a performance-based approach has challenges, it can deliver benefits in terms of safety, resilience, sustainability and cost, and is aligned with the general evolution of the structural engineering field

https://doi.org/10.2749/newyork.2019.0339
Distributed by Structurae