Effects of various design parameters on system-level fire fragility functions for steel buildings

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The existing literature in fire engineering is mostly based on single component study of structures, as opposed to system-level building performance. In current practice, fire does not need to be considered as part of the structural design of the building. The required fire protection for steel components in a building is based on prescriptive design guidelines, which are based on standard fire tests on individual structural members. In addition, the fire-structure engineering has primary focused on deterministic analysis, while the field is moving towards performance-based design in recent years. Meanwhile, the scenarios leading to a fire event and the performance of the structure at elevated temperatures involve a great level of uncertainty.

This work focuses on fire-structure interaction with the objective of developing fire fragility functions that capture fire damage uncertainty for the entire building (i.e., at the system-level). A fragility function provides the probability of exceeding a damage state for a given intensity measure of a given hazard. Fire fragility functions can be developed to measure the expected losses based on performance of a building structural system, rather than a single component. Different functions can be developed for buildings with different typologies (e.g. high-rise steel building with moment resisting frame, low rise steel building with bracing).

This presentation derives fragility functions based on stochastic analyses of prototype buildings. In developing the fragility functions, uncertainties in the fire model, the heat transfer model and the thermo-mechanical response should be considered; but such a large number of random variables adds to the complexity of analysis and the computational time. Based on a sensitivity analysis for steel gravity frames, this work identifies the most important input parameters to be considered as random variables when developing fire fragility functions for an entire building.

The sensitivity analysis for a multi-story steel building prototype is completed considering uncertainties at the compartment and building levels. At the compartment level, uncertainty in the fire scenario, compartment geometry, applied load, thermal and mechanical properties of steel and insulating materials are considered. At the building level, the influence of fire-resistance rating, building height, and occupancy type are studied. The results of this study identify the local and global parameters needed as part of deriving system-level fire fragility functions for a steel building.