ABSTRACT

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The resistance of a building to fire is the ability of the structure to withstand a combination of gravity loads and the induced thermal loads without undergoing failure either during the heating or cooling phases of the fire. Many researchers internationally have investigated the performance of steel-frame buildings in fire. However, few of them have examined U.S. building construction practices.

This project focused on the thermal and structural behavior of simple (shear) connections used in steel-frame buildings through experimental and numerical investigations. These connections include shear-tab, single-angle, and double-angle connections both all-bolted and all-welded. The experimental approach included the use of high-temperature ceramic fiber radiant heaters, vertical loading, and advanced thermal instrumentation. Isolate lap joints were heated to target temperatures and loaded to evaluate the isolated failure modes of simple connections. These failure modes included bolt shear and plate bearing. Large-scale composite beams with simple connections were subjected to a combination of heating and loading. These tests evaluated failure modes of simple connections as a part of a floor system subjected to fire loading conditions. While the composite beams were able to sustain the service level loads at elevated temperatures, the shear-tab connections fractured during the cooling phase of the test. Single-angle and

double-angle connections did not fail, rather prying of the angles was observed after the cooling phase.

Sequentially-coupled thermal-structural 3D finite element models were developed to evaluate both the thermal and structural response of composite beams with simple connections. This modeling approach accounted for temperatures-dependent material properties and the force-slip behavior of the shear studs. In addition, these models included contact definitions between the connection elements to simulate the bolt bearing behavior on the connection. A parametric study was conducted to evaluate the effects of various parameters on the capacity of simple connections at elevated temperatures. Variations in connection geometry, fire resistance rating, concrete deck type, continuous reinforcement were considered.

The thermal and structural behavior of simple connections was evaluated as an isolated connection, as a part of a one-bay composite beam, three-bay composite beam, and as a part of a full ten-story office building. The results of the parametric study were evaluated at a full building scale. Compartment, full-story, and moving fires were simulated in a ten-story office building. The fire resistance rating of structural members varied to understand the most cost efficient and effective fire resistance rating to withstand design fires. The results were compared with simplified methodologies developed by previous researchers to provide a simple design method without having to perform extensive thermal and structural analyses.