ABSTRACT

Francisco, Timothy W. Ph.D., Purdue University, August 2014. Structural Integrity of the Composite Slab in Steel Gravity Framing Systems. Major Professor: Judy Liu.

Gravity frames in steel buildings are inherently simple systems, with beam-to-column connections designed only to resist shear, and composite slab with ribbed metal decking designed for bending or diaphragm action. This simplicity has led to questions regarding the structural integrity or robustness of these systems. This research is part of a collaborative research project studying the structural integrity of steel gravity framing systems composed of steel beams and girders with composite slab on metal deck.

For the portion of the research conducted at Purdue University, investigation focuses on the composite slab. The concept of structural integrity is often tied to the idea of a column removal scenario, where the structure would be required to develop alternate load paths. The mobilization of the composite slab as a part of this behavior, theorized to be via membrane or catenary action, shifts the loading in the slab from bending to primarily tension. An initial phase of component tests on the concrete slab on metal deck includes uniaxial tests to evaluate behavior in both orthogonal directions with respect to the deck corrugations, and shear and tension tests of the sidelap splices. Parameters include metal deck thickness and type of sidelap (e.g., button punch, screw, weld). A second phase includes uniaxial tests of the slab transverse to the deck corrugations with additional reinforcement and tension tests of the support fastener connections between the metal deck and beams and girders. An effort is made to apply forces to the specimens in such a way as to be consistent with loading expected in a column removal scenario.

The results from the component tests provide important information regarding the response of the composite slab to expected column removal forces. The composite slab is shown to be weak in the transverse direction regardless of sidelap engagement and strong but susceptible to debonding in the longitudinal direction. The experimental results also cast doubt on the ability of the support fasteners to develop the longitudinal strength. These results both support and conflict with various assumptions that have been previously made regarding composite slabs in computational column removal simulations.

The acquired experimental data is evaluated from a computational perspective, building on previous work. Subassembly models are created to validate against the component level tests, and the lessons learned are extended to system level modeling. Further model refinement at the system level is accomplished through special consideration of the composite slab to girder connection. Additional parametric studies are carried out to establish the effects of these new adjustments on previously established parametric relationships. These refinements, especially the explicit realistic consideration of the support fastener connection, reduce the capacity of the system below expected gravity loading levels. Some suggestions for improvement are provided.

This research provides an important update to knowledge regarding the contribution of the composite slab to structural integrity in steel gravity framing systems, both in terms of experimental data and computational representation. It is expected that this work will lead to improved evaluation of both new and existing structures.