Public Abstract

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Title:Experimental and Analytical Evaluation of Disproportionate Collapse Flat-Plate Buildings

Reinforced concrete flat plate buildings without continuous integrity reinforcement may be vulnerable to disproportionate collapse if a supporting structural member was lost in an abnormal event. This research forces on the evaluation of potential of disproportionate collapse in older flat-plate structures subjected to the loss of a supporting column in extreme loading events. If a supporting column fails, then the load was carried by that column must be redistributed to the surrounding slab-column connections, which in turn may results in a disproportionate collapse over an entire building or a large portion of it. This progression can occur if the punching shear strength of the surrounding connections is not sufficient.

In order to make the most accurate determination of the potential for disproportionate collapse of flat plate structures, this research seeks to accurately evaluation the punching shear capacity of slab-column connections using the conditions present in a potential collapses event. The in-plane lateral restraint provided by the floor slab can enhance the punching shear strength of surrounding slab-column connections and may be significant. In addition, the post-punching capacity of the original failed slab-column connection may reduce the amount of load to be redistributed to the surrounding connections. In order to investigate the effects of lateral restraint and post punching capacity, six restrained and unrestrained static tests was conducted at 1% and 0.64% reinforcement ratios. The static tests showed that the punching shear capacity can be increased 2-8% as lateral restraint stiffness varies from 17 to75.6 kN/mm but the increase is highly related to the in-plane lateral restraint stiffness. The tests also indicated that the slab without integrity reinforcement can develop 54% of maximum post- punching strength after punching. However, this capacity decreases dramatically as the deflection increases to a large amount after punching failure.

Since isolated slab-column testing cannot fully represent behaviors of an actual building, multi-panel testing was done at a sub-structure system level. The specimens consisted of two 9 column portion of a flat plate building, one tested with an exterior column instantaneous removal and another tested with an interior column instantaneous removal. The tests further investigated the dynamic load redistribution, punching, and post-punching responses in a flat-plate structure.

The multi-panel tests (with interior and exterior column removal) showed that flat-plate slabs are vulnerable to disproportionate collapse at load levels of approximately 50% of their design capacity. The recorded lateral movements on columns in the tests verified the existence of compression membrane forces in continuous slab panel. Compressive membrane forces form after a column removal and gradually transition to tension membrane forces at deflections approaching the slab depth. Punching failure did not happen in compressive membrane phase, but in the tension membrane phase and tests showed that pre-existing damage in flat-plate structures (from prior overloading or shrinkage cracking) may impede the formation of compressive membrane forces in the slab. Dynamic removal of a supporting column resulted in a dynamic load amplification factor (DLAF) of approximately 1.3. Therefore, surrounding connections need to be able to carry at least 30% more than the predicted redistributed static load in a collapse analysis.