Experimental Study of Drop-Panel Effects on Response of Reinforced Concrete Flat Slabs after Loss of Corner Column

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INTRODUCTION

Progressive collapse is defined by ASCE/SEI 7 as “the spread of an initial local failure from element to element, eventually resulting in the collapse of an entire structure or a disproportionately large part of it.” Although progressive collapse is a low-probability phenomenon, the injuries and losses incurred in the event that it takes place could be very severe. Design guidelines have proposed design procedures to evaluate the likelihood of progressive collapse of a structure following the notional removal of vertical load-bearing elements (columns and walls). Resistance to progressive collapse is achieved either implicitly—by provisions of minimum levels of strength, continuity, and ductility—or explicitly by: 1) providing alternate load paths so local damage is absorbed and major collapse is averted; or 2) providing sufficient strength to structural members that are critical to global stability. The alternate load path method is also frequently used to design structures in resisting progressive collapse due to its independence of abnormal loading conditions. According to this approach, if a primary load-bearing element, such as a column or wall, is destroyed during an extreme loading event, an alternate load path must be generated to redistribute the load initially carried by the lost columns or walls. To study the behavior of a reinforced concrete (RC) frame after the removal of one or more columns, several researchers experimentally investigated the RC frame against progressive collapse. These studies have significantly improved the state-of-the-art standard of protective design and added to the database on progressive collapse behavior of RC structures.

However, the majority of the previous tests focused only on beam-column subassemblages without including the slabs or beam-column-slab substructures. In typical flat-slab or flat-plate structures, no beams contributed to the redistribution of the load previously borne by the lost corner column. Thus, they have greater vulnerability to progressive collapse compared to the beam-column-slab structures. Moreover, flat-slab and flat-plate structures are popular structure types and have a high occupancy rate. Hence, it is important to determine the extent of vulnerability of these structures in the event of column removal. Unfortunately, few experimental studies have been conducted on this subject to date. Thus, to attain a more comprehensive understanding of the behavior of reinforced concrete (RC) flat slabs in resisting progressive collapse and to quantify the influence of the drop panel on the performance of flat slabs against progressive collapse, two series (ND and WD) of one-third-scale specimens were tested under monotonic loading to simulate axial loading in the corner column. The experimental results highlighting the behavior, such as force-displacement responses, crack patterns, and failure mechanisms, are discussed. A comparison of the performance of these two series of specimens revealed that incorporating drop panels into the flat slabs would increase the first peak-resistance capacity by up to 124.7% and significantly reduce the likelihood of progressive collapse.

RESEARCH SIGNIFICANCE

The performance of RC flat slabs—with or without drop panels—in resisting progressive collapse caused by the loss of a corner column was evaluated in this study. The primary objective of this paper is to study the drop-panel effects on the vertical load-displacement relationship, crack pattern, and failure mechanism of the flat slabs by comparing the test results. This study can help structural engineers gain a further understanding of the resistance mechanism of flat-slab structures against progressive collapse and provide evidence for the validation of existing numerical modeling approaches.

EXPERIMENTAL PROGRAM

Design of test setup

It is well-known that progressive collapse events are dynamic phenomena. In-place tests represent the preferred