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Testing and analysis of composite floor systems under peripheral column removal scenarios

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Abstract

This paper presents an experimental study on the behaviour of a composite floor system with end-plate connections under a peripheral column removal scenario. The floor system comprised bridging beams, peripheral supporting columns and concrete floor with profile decking. In the specimen design, end-plate connections were used for the primary beam-column joints, and bolted web connections were adopted for beam-beam joints. Due to the constraints in structural laboratory, the two-bay by one-bay floor was scaled down to a 1/3 scaled model. A special loading scheme was designed so that displacement-controlled six-point loads were applied to the floor in order to represent uniformly distributed loads on the floor. Test results showed that the floor system could develop tensile membrane action to prevent progressive collapse. However, with increasing vertical displacement, the endplate at the beam-column joints fractured and the concrete in the composite floor was crushed. In the end, conclusions were drawn to shed light on the design of composite floor systems against progressive collapse.

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Keywords: Progressive collapse; Composite floor system; End-plate connection; Experimental tests; Finite element modelling;

1. Introduction

Progressive collapse denotes localized failure of a member triggers failure of adjoining members, and results in collapse of the entire of the structural system or major part of the system at last. After the notorious event "9.11" in

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the United States, more and more codes and standards focused on the progressive collapse. For instance, GSA[1] and DOD[2] recommend alternate path method to consider progressive collapse under extreme load. And Chinese standard JGJ99-2015[3] and CECS392-2014[4] also adopt the same way. Corresponding to these, column removed method was applied to research widely. For example, Yasser Alashker et al. [5] investigated the performance of steel composite floors, in which steel beams were attached to columns through shear tabs, against progressive collapse under internal column removal scenario. They found that the majority of collapse resistance came from the steel deck and that, for the system considered, increasing connection strength by adding more bolts might not be that beneficial in increasing overall collapse strength. Eric S. Johnson et al. [6] investigated the experimental behavior of a half-scale steel concrete composite floor system subjected to column removal scenarios. In the experiment, the water in containers was used as uniformly distributed load to evaluate the capacity of the floor system. It was concluded that despite the load redistribution seen in these tests, the observed capacities are below the extreme event load combination that is commonly used when designing to prevent progressive collapse, so the current design practice for steel gravity framing is likely not sufficient to meet this criterion. Given all above, in this paper, column removal method was also adopted to investigate the performance of the composite slab.

Previous experimental study mainly concentrated on internal column loss, Florea Dinu et al. [7] employed experimental and numerical method to study a 3-D steel frame system under column loss and learned that the system was capable of developing large deformations associated with catenary response in the beams without failure of the connections. And the beam ultimate rotation is larger than the deformation limit given in the codes. Qiu Ni Fu et al. [8] studied load-resisting mechanisms of 3D composite floor systems under internal column-removal scenario and concluded that the contributions of composite slabs with inner beams at ultimate state accounted for at least 1/3 of the total vertical load. However, few experiment research was carried out on the peripheral column loss in composite floor system.

In this paper, the performance of a composite floor system under a peripheral column loss against progressive collapse was studied experimentally. The behavior of the system was very different from the previous study. The load-displacement curve and the failure mode of the system would be discussed in this paper.

2. Experimental program

2.1. Test specimen

Given the space constraint, the specimen was 1/3 scaled down from a substructure extracted from a steel frame-composite floor building, whose layout was shown in Figure 1. The specimen was composed of two bays and was extended by 1/4 of neighbor span to provide restraint along three edges. The restraint system was designed to link to the specimen and was anchored to the ground to provide enough horizontal and vertical restraint. The overall height of the specimen was 1.4m, and the size of each bay is 2mX3m. Besides, the connections of girder to column adopted flush end plate with bolts, while double-angle cleat connections were applied to joints of girder to beam and beam to column. The details of each connection were illustrated in Figure 2. Furthermore, the composite slab comprised profiled steel decking, which was 40mm deep and 0.9mm thick, and concrete slab, whose thickness was 65mm with reinforcement mesh (6 at 200mm spacing in both directions) inside. Figure 3 shows the profiled decking. The shear studs were welded on steel girders and beams spaced at 75mm and 85mm separately.