Opening effect on punching shear strength of RC slabs

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Abstract

Punching shear failure can happen in reinforced concrete flat slabs due to the development of high shear stresses in the slab-column connection area. These shear stresses are increased when openings are created, since the presence of openings reduce the concrete area that sustains the shear stresses. In this paper, finite element analysis (FEA) with the damaged plasticity model for concrete in ABAQUS is performed to simulate the opening effect in reinforced concrete slabs without shear reinforcement. A previously tested and analyzed interior slab-column connections is considered. The effect of the location and the size of the opening on the punching shear resistance are investigated. The punching shear capacity of the analyzed specimens is calculated using the equations of two current design provisions for punching shear (ACI 318-14, Eurocode2-2004) and compared with the numerical results. A probabilistic analysis using Monte Carlo simulation for both design codes is considered. Finally, fragility analysis is performed in order to estimate the probability of the estimated punching shear resistance related with the opening size and distance.

Keywords: opening effect; concrete slabs; punching shear; crack pattern; finite element analysis; design codes; Monte Carlo simulation; Fragility analysis.

1 Introduction

Reinforced concrete flat slabs are often vulnerable in punching shear failure. If due to architectural reasons openings are needed near to the connection area, the volume of concrete that can resist the punching shear is reduced. While, flat slabs started to be tested in the 1950s by Elstner and Hognestad (1956) [1] and later by Moe (1961) [2], flat slabs with openings started to be examined only by recent researchers, such as, El-Salakawy et al. (1999) [3], Teng et al. (2004) [4], Bu and Polak (2009) [5], Borges et al. (2013) [6] and Anil et al. (2014) [7].

The punching shear code provisions are based on empirical formulations derived from the tests. ACI 318-14 [8] adopts the critical shear perimeter at a distance d/2 from the loaded area (column), while the EC-2 2004 [9] considers the control perimeter, at a distance 2d from the column's face. EC-2 2004 considers the critical shear perimeter with circular ends, while ACI 318-14 adopts the critical shear perimeter to be rectangular. Both codes adopt a reduced critical perimeter depending on the size and the location of the opening. A part of the controlled perimeter contained between two tangents drawn to the outline of the opening from the center of the loaded area (top surface of

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