39th IABSE Symposium – *Engineering the Future*
September 21-23 2017, Vancouver, Canada

Finite element investigation of the compressive membrane action effect on concrete slabs

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Abstract

The current design codes for punching shear resistance of flat slabs are based on empirical formulations derived from test results of isolated slab-column connections, where the compressive membrane action was ignored. Testing continuous slab systems is very uneconomical and in most cases not possible. In this paper, finite element analyses (FEA) are performed to investigate the structural performance of continuous slabs. A previously tested and analysed isolated slab with larger in-plane dimensions and different boundary conditions is considered. The FEA results indicate that the shear capacity of the continuous slab is much higher compared to the capacity of the isolated slab. The numerical models are used to examine the effect of low reinforcement ratio in the response of the continuous slabs. Finally, a comparison between analytical results and code provisions indicates the conservatism of the design codes.

Keywords: membrane action; concrete slabs; punching shear; crack pattern; finite element analysis; reinforcement ratio; design codes.

1 Introduction

Punching shear failure in reinforced concrete flat slabs is brittle. Inclined cracks are developed inside the slab and finally form a major inclined crack that leads to the failure. When this crack reaches the compressive zone of the slab, a punching shear cone around the column is formed leading to punching shear failure. Many research studies (e.g., [1][2]) have been performed in order to examine the punching shear failure of reinforced concrete slabs. In these studies, the experiments considered isolated slabs limited by the line of the contra-flexure at a distance of 0.22L, where L is the centre-to-centre span between the columns. These isolated slabs were not restrained in lateral in-plane movement and were simply supported around the edges. The test results of these isolated specimens were used as the basis of the design codes' methods for punching shear resistance of flat slabs.

In continuous reinforced concrete slabs, the tensile strains at the mid-depth of a slab's depth lead to an expansion of the slab, creating horizontal displacements. However, the lateral stiffness of the columns opposes this expansion by imposing compressive in-plane restraining forces. This phenomenon, that is called compressive membrane action, increases both the flexural and the shear capacity of the slab. Research was performed in order to examine the effect of the

https://doi.org/10.2749/vancouver.2017.1082
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