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Punching of flat slabs with in-plane forces

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ABSTRACT

The experimental analysis of reduced scale flat slab models under punching, subject to in-plane forces is described and the results are compared with the Eurocode 2 (2004) [1] provisions, the FIP Recommendations for the Design of Post-tensioned Slabs and Foundation Rafts (1998) [2] and ACI 318-08 (2008) [3], to evaluate their validity. The tests presented here consist of two sets of experimental models: Ramos's tests Ramos (2003) [10] with six reduced scale flat slab specimens and Regan's tests Regan (1983) [7] that comprised seven experimental specimens. This work aims to improve the understanding of the behaviour of flat slabs under punching load, in order to properly evaluate the effect of the in-plane forces on the punching resistance.

1. Introduction

Flat slab structures are, nowadays, a common structural solution for residential and office buildings. They are an economical structural system, they simplify and speed up site operations, allow easy and flexible space partitioning and reduce the overall height of buildings. Although simple in appearance, the flat slab system presents a complex behaviour, especially in the slab–column connection. The punching resistance is an important subject in the design of concrete flat slabs and frequently is the conditioning factor in choosing its thickness. The punching failure mechanism results from the superposition of shear and flexural stresses near the column and is associated with the formation of a pyramidal plug of concrete which punches through the slab. It is a brittle and local failure mechanism. Despite that it can be the origin of a progressive collapse, and in some cases a global structural collapse. In fact, the loss of a support in a slab–column connection leads to the increase of stresses in the nearby slab–column connections and enhances their probability of failure.

Punching of slabs, which are subject to in-plane compression, is a design issue primarily for post-tensioned flat slabs and for bridge decks. In the former the compression results from the prestress, while in the latter it arises from the deck's action as a compression flange and/or a local compressive membrane action developed due to restraint from the surrounding structure. Where a bridge deck acts as a tension flange a punching load may act simultaneously with an in-plane tension.

Relevant code of practice recommendations are written largely in the context of flat slab floors. The approach of Eurocode 2 [1] is however quite general and is to increase the shear resistance of an ordinary rc slab by a fraction of the mean in-plane stress, taken positive for compression and negative for tension.

The FIP recommendations [2] use the same control perimeter and almost the same shear resistance for slabs without in-plane forces as EC2, but treat the effect of in-plane compression by the addition of the load at decompression of the slab's top surface near a column. This involves factors such as the moments due to prestress, which are not considered in EC2.

ACI 318-08 [3] is similar to EC2 in considering the increase of shear resistance to be a fraction of the in-plane stress, although the base value for zero in-plane stress is slightly different from that for a rc slab and the control perimeter is closer to the column than in EC2. The fraction of the in-plane stress is considerably higher in ACI 318-08 and, within the stress range treated, the effect of in-plane compression is significantly greater.

Although there has been some experimental research on the punching of post-tensioned slabs done by several authors (Scordelis [4], Pralong [5], Shehata [6], Regan [7], Hassanzadeh [8] and Silva [9]), the isolation of the effect of in-plane forces in such tests is difficult because of the simultaneous effects of moments due to prestress, direct support of shear by inclined tendons near columns and other factors. Code treatments of overall resistance differ widely in the evaluations of individual effects.

It is also difficult to use the results of research on compressive membrane action, largely because of the complexity in the

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