Abstract

Reinforced concrete slabs with uniform thickness are common in residential and commercial buildings but can also be found in other types of structures. Such slabs are susceptible to punching shear failures, where a supporting column penetrates through the slab and leads to an immediate local failure that may trigger a progressive collapse of the building. Provisions for punching shear in most codes of practice are still mainly empirical, calibrated on the basis of experiments on test specimens that traditionally model only an isolated part of the slab within the points of contraflexure around the column. However, the punching behavior of actual continuous slabs may be influenced by effects that cannot occur in isolated specimens, such as moment redistribution between hogging and sagging moments, which changes the location of the points of contraflexure, and compressive membrane action. These effects can lead to higher punching strengths of actual continuous slabs compared to isolated specimens.

The first part of the thesis introduces an axisymmetric model to analyze the influence of these effects on the flexural deformations of continuous flat slabs. Combined with the failure criterion of the Critical Shear Crack Theory, the model can be used to predict the punching capacities of such slabs. Good agreement was found between the model predictions and the results of some unconventional punching tests from the literature. A simplified method, sufficiently straightforward to be used in design or assessment and given in a format compatible with the punching provisions of the Model Code 2010, is also proposed for calculating the load-rotation curves of continuous slabs.

The second part of the thesis contains the results of a test campaign comprising 13 isolated symmetric punching specimens. The study focuses on the influence of the size of the supported area and the slenderness of the slab. Other investigated parameters are the flexural reinforcement ratio and the presence of shear reinforcement. A novel experimental approach is used for tracking the formation and development of internal cracks. Measurement points were installed inside small holes drilled on the slab soffit on two sides of the column in the regions were punching cracks were expected to appear. Displacements of these points at various stages of loading were followed with a high-precision coordinate measuring arm. In most cases, the punching failure cracks were seen to develop independently of the flexural cracks, either appearing at the moment of failure or, in some cases, already at earlier stages of loading. Although the slabs were nominally axis-symmetric, different crack development patterns could be observed on the two monitored sides of the columns.

On the basis of the experimental evidence, a new punching model is proposed for slabs without shear reinforcement. Punching failures are assumed to occur due to reaching a critical triaxial stress state below the flexural cracks in the compression strut and a consequent formation and propagation of a failure crack. The proposed model uses the theory of plasticity with a general triaxial yield criterion together with an effectiveness factor based on fracture mechanics that is a function of the depth of the compression zone and the size of the column. The influence of membrane forces in continuous slabs on their punching strength is taken into account by adjusting the depth of the compression zone.

Keywords

continuous slabs, compressive membrane action, Critical Shear Crack Theory, interior slab-column connections, Model Code 2010, moment redistribution, punching shear model, punching tests, reinforced concrete flat slabs