Summary

Flat slabs are commonly used in buildings due to their easiness of construction and economy. In order to keep these advantages, columns are usually not continuous through the slabs in multi-storey buildings. In these cases, the slabs are subjected to large compressive stresses at the support area of the columns, which can exceed the uniaxial compressive strength of the concrete of the slab. This critical zone is in addition subjected to large shear forces and bending moments due to the loads applied on the slab. This leads to a series of potential failure modes: crushing of the concrete of the slab between columns, flexural failures or punching shear failures. Most research has previously focused on the influence of bending of the slab on the column strength. However, no works have provided in-depth investigation of the strength of the slab when large column loads are applied.

In this research, an extensive experimental programme has shown that the stresses applied at the support area of the columns can be significantly larger than the uniaxial compressive strength of concrete. The test results have clearly shown that no special confinement or load transfer devices are required between columns for most cases (moderate column loads). In addition, two phenomena have been observed. The first one is a reduction on the flexural strength as column loads are applied. The second corresponds to a significant increase on the punching shear strength and deformation capacity with column loading.

Existing theoretical approaches for flat slab behaviour and strength are shown not to be directly applicable for slabs subjected to large column loading. In this research, the principles of two general theories (the theory of plasticity and the critical shear crack theory) are thus used to investigate such cases. The theory of plasticity allows calculating a plastic failure envelope accounting for bending and column loading, whereas the critical shear crack theory, which in this work as been further investigated theoretically, is used to derive a failure criterion accounting for punching shear failure in presence of column loading. The results for both theories are finally presented in terms of a single interaction diagram between column loading and slab loading (bending and shear of the slab).

The theoretical approaches require however the help of rather refined numerical tools for estimating the strength of a flat slab. In order to use the theoretical approaches for design, a simplified approach has been developed, allowing to calculate the strength as well as the deformation capacity of flat slabs. This tools were implemented in a design method for slab-column joints in multi-storey building. This design approach allows to derive simplified interaction diagrams that can be compared with the loading history of the structural element analysed.

Keywords: flat slab, slab-column joint, reinforced concrete, self compacting concrete, confined concrete, theory of plasticity, critical shear crack theory, punching, practical applications