Abstract

Reinforced concrete (RC) flat slabs supported by slender columns are often used as gravity load resisting system for buildings. In regions of moderate and high seismicity such buildings are typically braced by RC walls, which carry the largest portion of the horizontal loads generated during earthquakes. Therefore, the slab-column system does not contribute significantly to the lateral stiffness and strength of the structure, but each slab-column connection must be able to accommodate the seismically induced drifts of the building while maintaining its capacity to transfer vertical loads from the slab to the columns. Otherwise, brittle punching failure of the slab occurs and the deformation capacity of the entire building is limited by the deformation capacity of the slab-column connection if the building is not designed to resist progressive collapse.

The first part of this work presents an experimental investigation on 13 full-scale internal slab-column connections without transverse reinforcement. The objective of the test campaign is to assess the influence of the loading history (monotonic vs. reversed cyclic) for different gravity loads and reinforcement ratios. The study shows that cyclic loading leads, in particular for slabs subjected to low gravity loads, to significant moment strength and deformation capacity reduction when compared to results obtained from monotonic loading tests. The effect of cyclic loading is more pronounced for slabs with low reinforcement content.

In the second part, a mechanical model is presented for predicting the moment-rotation relationship of interior slab-column connections without transverse reinforcement when subjected to seismically induced drifts. The model accounts explicitly for the three load transfer mechanisms between slab and column contributing to the unbalanced moment resistance, i.e., eccentric shear, flexure and torsion. The moment resistance and deformation capacity are deduced from the intersection of the moment-rotation curve with a failure criterion that is based on the Critical Shear Crack Theory and distinguishes between monotonic and cyclic loading conditions. The model predicts well the moment strength and the deformation capacity of slabs tested within this research and reported in the literature.

The third part of this thesis proposes an extension of the mechanical model for the moment-rotation relationship presented earlier to account for the hysteretic behaviour and cumulative damage effects on slab-column connections subjected to cyclic loading. A hysteretic moment-curvature relationship is proposed for the radial direction, based on local deformation measurements from the cyclic tests. Cyclic damage is considered by adopting a damage index proposed by a previous study. The extended model predicts more accurately the response of cyclic tests than the simplified approach based on the monotonic model.

Finally, based on the theoretical investigation of the two previous parts, two methods are proposed for the numerical analysis of flat slab buildings to simulate the column deformation and the slab deformation until midspan. First, an Effective Beam Width method is presented and compared to test results of flat slab buildings with over-hangs. Then, a simplified method is proposed for the analysis of slab-column connections not part of the lateral force-resisting system. This method allows estimating the contribution of column and slab deformation to the interstorey drift.

Keywords: reinforced concrete flat slabs, slab-column connection, seismic loading, Critical Shear Crack Theory (CSCT), interstorey drift, unbalanced moment, load history, deformation capacity, lateral force-resisting mechanisms, Effective Beam Width method