Summary

Punching of reinforced concrete and prestressed slabs is usually a critical failure mode for the design and verification of structures such as flat slabs or bridge slabs. Although codes of practice propose several rules for common cases (usually with an empirical basis), they do not provide a general tool for studying the punching strength because they are not based on a physical model. Furthermore, a better accuracy in the determination of the punching strength is needed when investigating the ultimate load of existing structures.

Recently, test results from a series of 10 concrete slabs without punching reinforcement (performed within this thesis) as well as different tests performed by other researchers allowed to check and validate the application limits of a failure criterion proposed by Professor Muttoni for slabs without punching reinforcement. This failure criterion defines the punching strength mainly as a function of the radial rotation of the slab in the vicinity of the column.

Even if a punching failure is predominantly a shear failure, the vertical displacements and the plate rotations before failure are governed mainly by the flexural characteristics of the slab. A computational model for the flexural behavior of concrete slabs has been developed, considering the different material non linearities and allowing also to include the effect of prestressing.

Finally, both the failure criterion and the computational model are merged into a physical model which is able to determine the punching strength of symmetrical slabs, with any flexural reinforcement layout (prestressed or not). The comparison between theoretical and experimental results shows good agreement, better than provided by current codes of practice.

With this physical model, it is also possible to determine the punching strength for particular cases, not covered by building codes. For instance, in the case of an inner column at a flat slab, it is possible to compute the enhanced punching strength due to the restraint effect exerted by the rest of the slab. The model can also be used to determine the failure load of a foundation plate, considering the interaction between the soil pressure and the slab displacement. Furthermore, it is possible to include temperature effects on the punching strength evaluating the loss of resistance due to fire exposure of the slab.

The proposed model is very flexible and can easily be adapted to the different cases which an engineer is confronted to. It revealed itself as a very helpful tool for determining the failure load of an existing structure as well as for designing the reinforcement layout for new projects.

Within this thesis, only axisymmetrical cases have been studied. To analyse border or edge columns as well as other non symmetrical cases, the model should be adapted.