Abstract

Since the first applications of structural concrete, the shear behaviour of one-way slabs without transverse reinforcement has been largely investigated. The theoretical and experimental research efforts have allowed identifying the various shear-transfer actions carrying the load. Nevertheless, currently in the scientific community there is no general agreement on the mechanisms of shear failure, on the parameters governing the shear strength and on the predominant shear-transfer actions. Hence, several mechanical models, based on very different hypotheses, and empirical formulations, calibrated on the available experimental results, have been proposed in the last decades. In addition, these experimental results have been traditionally obtained from tests on simply supported beams subjected to point loading, whereas in most one-way slabs without transverse reinforcement in practice (foundations, retaining walls, slabs of cut-and-cover tunnels, silos) the support and loading conditions are typically different.

This thesis has therefore the objective to provide new experimental data on reinforced concrete members without transverse reinforcement subjected to different loading and support conditions, to increase the understanding on the mechanisms of shear failure and to develop a mechanical model based on the new experimental evidence.

In the first part of this thesis, the experimental results of 25 tests on 20 beams without transverse reinforcement subjected to different loading (concentrated and distributed load) and support conditions (simply supported beams, cantilevers and continuous beams) are presented. Refined measurement techniques allowed detailed tracking of the development of the crack pattern up to failure. The results show that the location, the inclination and the kinematics of the critical shear crack play a major role on the shear strength. Moreover, the amount of shear transferred by the various potential shear-transfer actions (inclination of the compression chord, arching action, residual tensile strength of concrete, dowelling action, aggregate interlock) has been estimated based on the experimental measurements and by using suitable mechanical models for each shear-transfer action. The analyses show that, for slender members, the shear-transfer actions contributing to the shear capacity are the inclination of the compression chord, the residual tensile strength of concrete, the dowelling action and the aggregate interlock, and the latter is the predominant one. For squat members or members in which the critical shear crack develops below the theoretical compression strut, differently, the arching action becomes governing.

In the second part of the thesis, a mechanical model, consistent with the main assumptions of the critical shear crack theory, is presented. The shear force that is transferred through the critical shear crack by the various shear-transfer actions is calculated by integration of simple constitutive laws and a failure criterion is obtained by summing the different contributions. The shear and deformation capacity and the location of the critical shear crack leading to failure can thus be calculated by intersection of the failure criterion with a load-deformation relationship. It is shown that the failure criteria obtained by integration of stresses at the crack surface can be approximated by power-law equations. Combining the power-law failure criteria with the load deformation relationship, a closed-form equation has been obtained. The closed-form equation provides almost identical results to the mechanical model and allows for direct design and assessment of existing structures. The mechanical model and the closed-form equation can be applied to members with different loading and support conditions. The accuracy of the two approaches has been checked against a large database of tests, showing a good agreement to the experimental results.

Key-words: reinforced concrete structures, shear strength, experimental programme, digital image correlation, shear transfer actions, mechanical model, critical shear crack theory, design equations