Abstract

Traditionally, the concrete strength is measured on cubes or cylinders having normalized dimensions, suitable vibration and curing conditions and their strength is assessed in laboratory under fast loading rates. However, the in-situ strength of structural elements can considerably differ from that of a small and homogenous control specimen due to a number of issues.

Notably, phenomena taking place during the consolidation process of fresh concrete may affect the compressive resistance of tall members as well as the bond strength of reinforcing bars located in top layers. During concrete consolidation, water migrates in the direction of the free surface while concrete settles downwards, phenomena referred as concrete bleeding and plastic settlement respectively. Under these circumstances, a decrease in the concrete properties near the upper surface is observed as well as a development of cracks and voids surrounding horizontal reinforcing bars, causing potential disturbances on the compressive stresses and affecting the mechanical engagement between bars and concrete.

In addition, the response of structural concrete may differ from that of material samples due to non-uniform stress states, the material brittleness, the cracking induced by imposed strains, the rheological response of concrete and the presence of embedded disturbances. As a result, the strength measured in material samples needs to be corrected with strength reduction factors to ensure suitable structural analysis.

In this thesis, an in-depth investigation is performed on the different phenomena affecting the compressive and bond strength of structural members. These aspects are assessed by means of several testing programmes instrumented with refined measurements techniques such as tomography and Digital Image Correlation.

An extensive experimental programme comprising 76 column and prism tests was carried out to evaluate the influence of casting position, loading direction and bar disturbances on the compressive resistance of structural elements. The detailed measurements performed at the fresh and hardened state resulted in the proposal of consistent design rules accounting for the investigated phenomena.

Focus was also given on the influence of material brittleness and the implications of internal stress redistributions on the structural response of reinforced concrete columns and compression zones of members in bending. The pertinence of the investigations were validated based on more than 400 column tests collected from the literature.

The implications of casting conditions on pull-out and spalling failures were also assessed by means of 137 pull-out tests on reinforcing bars presenting variable diameter, concrete cover, casting height and embedded length. The investigations resulted in the proposal for a physically-consistent approach, evaluating the pull-out resistance as function of casting conditions and reinforcement characteristics.

Finally, the phenomenon of cover spalling was examined with respect to the action of a radial inner pressure, as originated by bond engagement or associated to the volumetric expansion of corroded reinforcement. The mechanisms inducing spalling were analysed by means of a comprehensive experimental programme comprising 56 specimens instrumented with Digital Image Correlation. A mechanical model is eventually proposed to evaluate bond-related cases of cover spalling.

Keywords: structural concrete resistance, compression, bond, spalling, bleeding, plastic settlement, casting position effects, strength reduction factors, Digital Image Correlation, tomography.