CERIS : Civil Engineering Research and Innovation for Sustainability

Integrated formulation of eco-efficient concrete with improved durability and specific incorporation of (new) waste by-products

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Summary

The growing concern about the ecological footprint has led to important efforts towards carbon neutrality. In the concrete industry, this necessarily involves improving the formulation of the mixtures, through matrix optimization, and replacing cement with other additions with potential for incorporation in concrete, such as industrial waste by-products, which are often wasted and deposited in landfills. Thus, this thesis seeks an integrated formulation solution for eco-efficient concretes with high compactness and cement replacement by (new) industrial waste by-products, filling the gaps that exist in the literature regarding the study of durability of this type of concrete. As a result, the matrix formulation will be based on a parameterization that guarantees high compactness and low permeability, with low cement and water contents, as well as the desired workability and performance. The selection and proportion of additions/waste will be specifically analysed in order to satisfy mechanical, time dependent and durability requirements.

This work is supported by a strong laboratory component and is divided into 4 main phases: (1) Characterization of the by-products (cementitious and pozolanic reactivities, shape, size and particle composition), development of the method and formulation of the eco-efficient concrete. A new model to predict the performance of the binder matrix is developed, with low cement content and high compactness and with variation in the type and dosage of additions; (2) Produce and test the specimens to characterize the mechanical (compressive, tensile splitting and flexural strengths and Young's modulus) and time dependent properties (shrinkage and creep) of concrete. The results of these tests are compared with the prediction models from the main codes and evaluated its suitability (and the need for corrections); (3) Produce and test the specimens to characterize the durability properties of the studied concretes: accelerated carbonation, capillary water absorption, migration of chloride ions, resistivity, and permeability to water. With these results, the evolution of durability properties for different ages of concrete maturity (including advanced ages) is assessed. Based on these results, models are developed/adapted to predict the service life of the new concretes in reinforced concrete structures, for different exposures to carbonation and migration of chloride ions. The concrete sustainability indexes are also analysed, where the use of local materials is an analysis parameter, benefiting from the reduction of costs and impacts associated with transport; (4) Finally, the characterization of the structural behaviour in reinforced concrete elements: pull-out tests, to assess rebars-to-concrete bond strength, and production and testing of beam elements with eco-efficient concrete and different rates of steel reinforcement, to characterize flexural and shear behaviour, both under service and failure conditions.

Keywords

Eco-efficient concrete, improved durability, concrete formulation, cement reduction, specific additions, industrial waste by-products.

Durability experimental tests: accelerated carbonation, resistivity, chloride migration; water permeability.