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Contribution to the sustainability of concrete structures. Development of structural elements in eco-efficient concrete with a cover layer in ultra-high durability concrete

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Summary

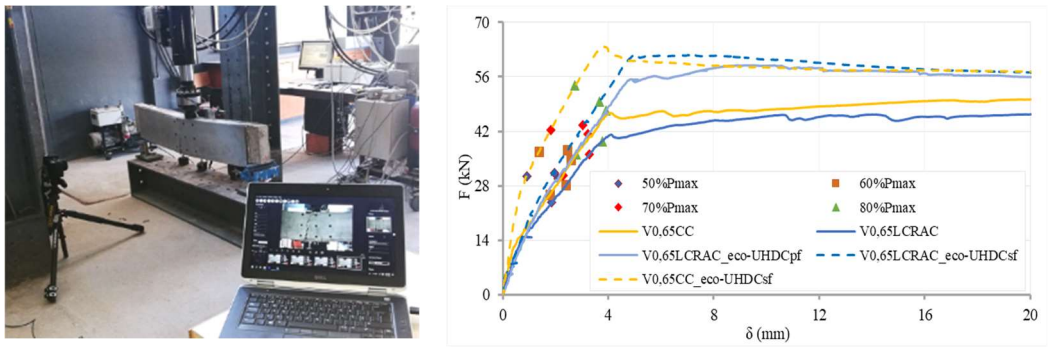
Climate change is currently a huge challenge, and this contributed to make the sustainability and decarbonization of the construction sector the main priorities today, as well as the investment in circular economy. Thus, the main goal of this thesis is to develop an innovative method to build structures, aiming to make them more eco-efficient, durable and with better performance. This method consists in adopt an eco-efficient ultra-high durability fiber-reinforced concrete (eco-UHDFRC) only in the cover layer, named as superskin, and in the core, a concrete with low cement content (LCC) and with recycled aggregates from construction and demolition waste (CDW), referred as LCRAC.

The work carried out has a strong experimental component and was divided into three stages: (1) In the first phase, formulation, production, and characterization of several mixtures of LCC with current aggregates, and in the second phase several mixtures of LCRAC, incorporating different CDW. Then an eco-UHDFRC was developed and optimized to achieve the maximum durability performance and, simultaneously, the minimum environmental impact. Regarding durability, tests were carried out in laboratory conditions as well as in situ, the latter case in Cape Verde; (2) Evaluation of the interface behavior between eco-UHDFRC and LCRAC. Slant Shear Tests were performed considering different types of surface roughness and different methods of applying the superskin, before or after the core casting; (3) Characterization of the structural behavior, both under service and failure conditions, of sixteen beams produced using the new concept, where the flexural stiffness, crack width and flexural strength were analyzed. Finally, a study was carried out to assess the sustainability of the concept developed, considering the mechanical performance (compressive strength of the concrete and flexural strength of the beam), the durability (carbonation depth, chloride diffusion coefficient, and estimated service life), and the environmental impact (GWP - global warming potential and Pe-NRe - non-renewable primary energy resources).

The results allowed to conclude that a beam executed with a LCRAC and with cover layer of eco-UHDFRC provides, comparatively to an equivalent and current reinforced concrete beam: i) an increase in flexural strength between 15 and 35%; ii) a decrease of the vertical deformation and of the crack width, under service conditions, that can reach 53% and 57%, respectively; iii) a significant increase of the estimated service life or a decrease of the minimum cover required; and iv) a significant increase in the sustainability indicator, with differences higher than 100%.

Keywords

Ultra-high performance fiber reinforced concrete, low-cement concrete, recycled aggregates concrete, durability, sustainability, concrete-to-concrete interface.



Flexural behavior of eco-efficient and ultra-high durability concrete beams: test set-up (left) and load-displacement relation (right).