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Minimising the carbon footprint of standard-compliant structural concrete by adopting low-binder LC^3 mix designs

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Abstract

Concrete is, as a matter of fact, the only construction material able to globally meet the growing demand for new structures and infrastructure, especially in the developing countries of the Global South. As a consequence, the already significant CO_2 emissions related to the construction sector, mainly attributable to the production of Ordinary Portland Cement (OPC), are expected to increase.
Rapid and effective solutions are needed to meet future demands sustainably and achieve carbon neutrality by 2050. Among these, reducing clinker in cement and reducing cement in concrete are seen as the most promising and ready-to-use ones. Limestone Calcined Clay Cement (LC^3) is widely recognised as the most feasible blended cement addressing the former. Whereas the latter is currently prevented by the restriction of a minimum binder content of 300kg/m^3 in most existing prescription-based Standards.
The goal of this work is to minimize the CO_2 emissions of standard-compliant structural concretes by adopting low-carbon and low-binder mixes, thus providing evidence for a performance-based update of the current prescriptive codes.
Several concrete mixes were designed to reduce the binder content to 250 kg/m^3 while targeting a wide range of structural strength classes. Mechanical and durability properties were tested and compared to the reference OPC concrete designed according to Standard prescriptions. A performance-based life cycle assessment was used to highlight the CO_2 reduction potential of the new systems. The results showed that LC^3 is suitable for structural concretes of a wide range of strength classes and additionally provides increased resistance to chloride penetration. Limiting the minimum cement content for a specific strength class was proven to be a conservative approach leading to overdesign and excess CO_2 emissions. Instead, the combined use of LC^3 and lower binder content allowed for -55% CO_2 emissions compared to the reference standard-compliant OPC without affecting the mechanical properties.

Keywords: Limestone calcined clay cement, structural concrete, carbon footprint, life cycle assessment, performance-based standards.