CERIS Civil Engineering Research and Innovation for Sustainability

Influence of CO_2 incorporation on the hydration of cementitious materials

Summary

The versatility and cost of concrete have made this construction material into the second highest consumed material in the world, only surpassed by water, in volume. Even though concrete presents a low embodied CO2 and energy, the immense concrete consumption throughout the world originates an estimated emissions of 5-8% of the total CO2 emissions annually. Additionally, it is important to remark that the major responsible for this concrete's environmental impact is cement, a concrete's component that is associated to an estimate of 80-95% wt. of the totality of the CO2 released from concrete production. Thus, in 2009, a Cement Technology Roadmap was developed aiming at reducing the carbon emissions of the concrete and cement industry. In this roadmap, four levers with major potential for an effective carbon emission reduction were identified. Recent studies in this field and revisions of the roadmap, point towards two of these technologies, as the strategies with major potential for curbing the CO2 emissions, namely Carbon Capture Utilization and Storage (CCUS) and Clinker Substitution. This thesis concentrates its investigation on the application of this CCUS technology into the life cycle of concrete and cement, while simultaneously implementing the clinker substitution technology.

Having defined the investigation strategy towards the reduction of the CO2 emissions, the investigation object of this thesis is a by-product of the construction and demolition waste (CDW) recycling process. More specifically, it is a by-product of the concrete waste recycling process, currently named cement paste powder (CPP). Even though the main objective of the recycling process is to attain recycled aggregates, studies have demonstrated that this process yields about 10-20% of CPP mixed with aggregated impurities. Additionally, other studies have demonstrated to obtained CPP with 90% vol. of purity out of concrete waste. Hence, the carbonation potential of CPP, and its binding capability after carbonation, uncovers a feasible prospect for the application of the carbonated material as a supplementary cementitious material, targeting the CCUS and clinker substitution technologies aforementioned. However, a feasible industrial application of this concept is still far from being applicable. The main impasses here are the long duration of the carbonation process (a minimum reported of 3 days), and the knowledge gap associated with the hydration reaction mechanisms of cementitious materials mixed with carbonated and recycled SCMs in its composition. Therefore, this thesis aims first at developing a short duration carbonation process for CPP with a duration of a few hours, investigating the parameters affecting the carbonation reaction, while simultaneously studying the chemical mechanism and reaction kinetics occurring throughout the carbonation process. Afterwards, the aims of the thesis deviate towards the investigation of the application performance of carbonated CPP in cementitious materials, namely in concrete, mortars and concrete blocks as an addition. These three types of cementitious products were selected considering that usually the main sources of CDW in either residential or non-residential buildings are reinforced concrete and masonry (mortars and concrete blocks specimens), thus aiming at the promotion of a circular economy. Furthermore, the application of this strategy to more than one cementitious specimen provides further information to the life cycle assessment chapter to be performed in the end of this thesis, analysing the CO2 mitigation impact of the strategy developed.

Overall, this thesis aims at developing a carbonated SCM, with the objective of reducing the environmental impact of the concrete industry. Thus, by performing an investigation oriented towards the industrial transformation of CPP into a valuable commodity and its application in the life cycle of concrete, this thesis aspires to impact on both the knowledge regarding the CO2 incorporation in cementitious materials and on its industrial application.

Keywords

Carbon capture utilization and storage, carbonation, cementitious materials, CO_2 uptake.

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