CERIS : Civil Engineering Research and Innovation for Sustainability

ECO2Alkacrete – Carbon Capture: Performance Enhancing CO_2-based Curing for Fully Recycled Alkali Actived Concrete

Summary

Concrete is the World's second most consumed material after water and is used in almost all building structures. However, the production of cement alone accounts for 7% of the total global CO_2 emissions. Despite the importance of this construction material to the economic development of any nation, stakeholders are gradually aware of non-Portland cement alternatives, with alkali-activated materials (AAM) as the top contenders. Early studies have shown the feasibility of AAM, in high-strength structural elements, based on activated fly ash (FA) or blast furnace slag (BFS) as sole binders. Nevertheless, FA production is withering in many other countries as a result of our motion towards more sustainable energy solutions and that of BFS has stopped entirely in Portugal as blast furnaces were replaced with electric arc ones. The most effective strategy to replace FA and BFS with technically/economically viable alternatives for AAM production is to use bulk-produced reactive calcium aluminosilicate wastes without clearly defined outlets. The top contenders are glass packaging waste rejects (WGR), municipal solid waste incinerator bottom ashes (MIBA) and electric arc furnace slag (EAFS):

- Glass packaging production amounted to ~1.5 Mt in Portugal (2017), comparable with the amount of cement produced, ~2.6 Mt (2018). However, even though WGR are mostly comprised of highly reactive soda-lime-silica glass, they contain a notable amount of contaminants from the incorrect separation of waste glass (30-70% of waste glass from kerbside collection are unrecyclable rejects).
- Portugal produced ~5 Mt of municipal solid waste (MSW) in 2018, 20% of which was incinerated with energy recovery. However, the process is responsible for a great amount of MIBA; ~100 kt/year of MIBA comes from Valorsul`s incineration unit treating most of Lisbon`s MSW and are accumulating in a landfill in the city's outskirts.
- EAFS is a calcium silicate waste from steel recycling with a production of >5 Mt/year in Europe. However, most of it is downcycled in road pavement construction. It has shown promising reactivity and is produced in bulk amounts that can make its incorporation viable in AAM.

To comply with the Paris Agreement and the UN 2030 Agenda for Sustainable Development, further measures must be undertaken to mitigate climate change by reducing the Construction industry`s CO_2 emissions. CO_2-based curing is known to enhance the performance of Ca-rich cementitious composites. However, little is known on the efficacy of the gas in AAM, especially with WGR, MIBA or EAFS. Recent preliminary results by the research team show a 5-fold increase in the strength of cement-free AAM based on MIBA or EAFS after 7 days of forced CO_2 curing and still with significant room for optimization. Given the scarcity of outlets for WGR, MIBA and EAFS, instead of landfilling or downcycling them, there is considerable scope to valorise them in the development of cement-free materials by taking advantage of their high activation potential. Furthermore, since they have a much lower carbon footprint than cement, yet with a high CO_2 storage capacity, the possibility of producing carbon-negative construction materials is closer than ever.

This project seeks to develop innovative CO_2-enhanced cement-free and fully recycled AAM as sustainable binding systems for mortar/concrete in conformity with European standardization (Figure I). A comprehensive experimental campaign will be carried out, focusing on a performance-based optimization of the AAM's mix design after a CO_2 cure, establishing the total permanent CO_2 capture capacity. Numerical models, using the previously obtained experimental data as input, will be developed, validated and used to conduct further parametric studies on the diffusivity of CO_2 within the specimens for maximum production output in practice. The technology will be evaluated based on its environmental performance via a life cycle assessment. After ensuring the material's safe use, measures will be taken to introduce it in a real application serving as a gateway for its future commercialization.

Figure 1. Alkali-activated concrete pavement blocks after an accelerated carbonation curing regimen.

ECO2ALKRETE

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Leading Institution

IST-ID – Associação do Instituto Superior Técnico para a Investigação e Desenvolvimento (Portugal)

CERIS Principal Investigator

Rui Vasco Silva
(rui.v.silva@tecnico.ulisboa.pt)

CERIS Research Team

António Duarte, Jorge de Brito, Luís Evangelista, Miguel Bravo, Catarina Farinha, Margarida Braga

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