CERIS Civil Engineering Research and Innovation for Sustainability

Aluminosilicate industrial waste-based alkali-activated concrete with forced carbonation

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Summary

After the promising results reported by many researchers, showing how the carbon-curing method can be used as an effective technique capable of enhancing the properties and performance of alkali-activated materials such as fly ash and blast furnace slag, the idea of applying this method on fully recycled alkali-activated materials (AAMs) was chosen to be investigated in this project. The precursors, from industrial wastes, selected for this experimental campaign are municipal solid waste incineration bottom ashes (MIBA), electric arc furnace slag (EAFS), and glass waste rejects (WGR). These were selected due to their availability, aluminosilicate nature, and potential environmental benefits. Using these three alkali-activated precursors, 200 mm × 100 mm × 80 mm pavement blocks will be produced. Afterwards, these pavement blocks will undergo two different curing conditions representative of a potential industrial production process (with or without CO_2 curing), including dry chamber curing (around 50% RH and 20 °C) and accelerated carbonation curing (5% CO_2 concentration and ~60% RH). The specimens from the two curing regimens will be compared in order to understand the effectiveness of the forced CO_2 stage on these proposed AAMs. Additionally, curing the pavement blocks with CO_2 will allow a permanent storage for it, making this project idea even more interesting in a context of climate change mitigation. Preliminary results of our research team have shown a 5-fold increase in strength after exposing alkali-activated concrete, with MIBA and EAFS used as sole precursors, to carbon curing. Following this line of research with encouraging results, the present PhD thesis has the following objectives: i) the performance of the CO_2-cured alkali-activated MIBA, EAFS, and WGR will be optimized; ii) the maximum CO_2 storage capacity will be determined along with the numerical modelling of CO_2 diffusivity of each compound; iii) the practicality of this technology for the market will be facilitated for its future commercialization. The following tasks will be undertaken to fulfill the aforementioned objectives, respectively:

- The MIBA, EAFS, and WGR precursors will be fully characterized as a step toward understanding their reactivity. Also, the alkaline activator solution will be optimized for maximum strength development of each of the precursors. Additionally, the chemical and mineralogical changes will be evaluated for further optimization.
- The CO_2 storage capacity of the specimens subjected to different carbon-enriched environments will be determined. For this reason, numerical models will be developed to predict the level of carbonation for each specimen according to its carbon curing conditions and specimen's geometry, dimensions, and composition.
- The reproducibility and stability of MIBA, EAFS, and WGR-containing and CO_2-cured alkali-activated concrete, will be demonstrated. Consequently, a life cycle assessment database of the raw material and their process will be established by using the outputs collected from previous tasks along with the previous knowledge already available.

Keywords

Alkali-activated materials, municipal solid waste incineration bottom ashes, electric arc furnace slag, glass waste rejects, CO_2 curing, CO_2 capture, pavement blocks, performance enhancement.

Carbonated MIBA pavement block.