CERIS Civil Engineering Research and Innovation for Sustainability

RInoPolyCrete – Recycled Inorganic Polymer Concrete: Towards a Cement-free and Fully Recycled Concrete

RINOPOLYCRETE

Project Reference

PTDC/ECI-CON/29196/2017

Leading Institution

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

Partners

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Funding

FCT – Fundação para a Ciência e a Tecnologia

Period

2018-2022

Total

233 825.23€

CERIS

233 835.23€

Project Website

rinopolycrete.tecnico.ulisboa.pt

Summary

Concrete is the World`s second most consumed material after water and is used in almost all building structures. However, its high environmental impact must be recognized; the cement industry accounts for 7% of the total global CO_2 emissions and is increasing. If this amount were gathered and spread across the entire area of Portugal, it would be 3 m high. In parallel, Portugal produces around 5 Mt of municipal solid waste (MSW) every year, 20% of which is incinerated with energy recovery. Despite being vital for the correct management of MSW, it is responsible for two by-products: MSW incinerated fly ashes and bottom ashes (MIBA). About 100 kt/year of MIBA come from Valorsul`s incineration unit treating most of Lisbon`s MSW (Figure 1), whereas MIFA is solidified/stabilized using cement and sent to a landfill. MIBA are transformed into a value-added product, which is used in road construction, but most of it remains vastly unused and is accumulating in several hills in the Mato da Cruz landfill.

Figure 1. MIBA sampling from monthly production stack.

To comply with the recently signed Paris Agreement, to mitigate global warming, further measures must be undertaken to reduce the cement industry`s CO_2 emissions with the introduction of technically viable alternatives. Furthermore, in view of the scarcity of outlets for MSW ashes, there is significant scope for the development of value-added applications for them. These issues can be tackled with the alkali activation of ashes to produce new binding systems. Stakeholders from various markets are gradually aware of the progress of non-Portland binder systems, with alkali-activated materials (AAM) as the top contenders. Early studies have shown the feasibility of AAM, in high-strength precast beams, columns, and slabs, based on activated fly ash (FA) or blast furnace slag (BFS) as the only binders. Since MIBA also exhibit high activation potential, an opportunity emerges to valorise them into a sturdy and durable monolithic construction material capable of encapsulating their hazardous elements.

The RINOPOLYCRETE research project set out to investigate an innovative combination of alkali-activated FA along with MIBA as the binder, and recycled aggregates from construction and demolition wastes as natural aggregate replacement. The alkali activation of MIBA, apart from being a technically viable alternative to cement and demonstrating a lower carbon-footprint, will also valorise a deeply unappreciated resource (i.e. MIBA) simultaneously immobilizing its hazardous elements within a new construction material.

The mission of project RINOPOLYCRETE is to reduce the environmental impacts of cement-bound materials (i.e. concrete and mortar) as a response to three societal issues:

- The cement`s immense environmental impact, by reducing its content.
- Huge production of MIBA and CDW, by incorporating them in the manufacture of new construction materials.
- Heavy metal contamination of soils from leachable MIBA, via their solidification/stabilization into a value-added product.

To accomplish this mission, three main objectives were defined:

1. Study the viability of totally replacing cement with alkali activated ashes.
2. Establish the influence of RCA, as natural aggregate replacement, in the production of alkali activated concrete and mortar specimens.
3. Facilitate the introduction and commercialization of AAM as an alternative to cement.

For each of these objectives, minor ones were defined. For objective no. 1, the research team will:

- Characterize and pretreat (Figure 2) the aluminosilicate precursors (i.e. MIBA, FA), with adequate reactivity for alkali activation.
- Evaluate the influence of varying contents of the alkaline activator on the strength development of different combinations of the solid precursor.
- Establish ideal curing regimens for the maximum long-term mechanical and durability performance of AAM.

For objective no. 2, the research team will:

- Analyse the role of recycled aggregates, in terms of their reactivity with the alkaline activator and ascertain the formation of new products of hydration capable of enhancing the ITZ`s microstructure.

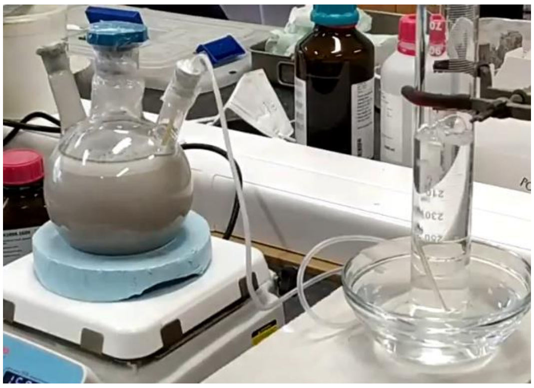

Figure 2. NaOH-based pretreatment of MIBA.

- Compare and correlate the properties of recycled aggregate containing AAM with those of conventional recycled aggregate concrete.

To achieve objective no. 3, the research team will:

- Demonstrate the reproducibility of AAM by correlating their properties with those of conventional concrete.
- Strive for compatibility of the manufacturing process and properties of AAM with existing standards and specification for conventional concrete (i.e. EN 206, EN 1338).
- Demonstrate the reduced carbon footprint and economic viability of AAM by means of a life cycle assessment and life cycle cost.

The tasks of this project included first a literature review on alkali activation of aluminosilicate wastes thereby allowing a comparison of the most recent findings to adequately adjust the mix design and manufacturing process according to the research team`s expectations throughout the investigation. The upcoming tasks involved extensive experimental studies of the various possible combinations of MIBA with other aluminosilicate precursors and the effectiveness of the dissolution process as well as the ideal accelerated curing regimens for maximized mechanical and durability-related performance. This would be achieved via a complete characterization of the raw materials used for concrete production (Figure 3) and taking into consideration the use of alkaline activators with varying NaOH concentration and SiO_2/Na_2O molecular relationships.

The following tasks would involve the use of activated MIBA, as complete replacement of cement, in the manufacture of concrete, using recycled aggregates as substitute for natural aggregates. This completely recycled mix will be evaluated in terms of its applicability in non-structural building blocks and in structural elements, wherein correlations will be made with the properties of conventional concrete with comparable mix design, to draw out practical rules and easily applicable correction factors that can facilitate the normalization of AAM.

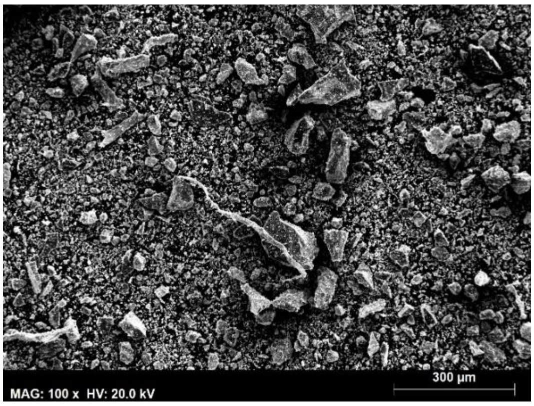

Figure 3. Scanning electron microscopy of MIBA.

Additionally, the results from this campaign will be used a life cycle assessment of the raw materials for alkali-activated concrete and mortars and to quantify the environmental impact reduction and economic viability for the commercialization of the proposed materials namely in the form of pavement blocks (Figure 4). This database will also include their toxicity information, which will be evaluated by means of leachability testing of the initial individual components and their alkali-activated monolithic form. This will allow establishing the product`s effectiveness at immobilizing hazardous elements within the MIBA. Further measures will be arranged with the research team's partners in Cascais` Municipality to study its behaviour in real conditions.

Figure 4. MIBA pavement block according to EN 1338.

The research team has extensive experience and knowledge in different complementary areas relevant to the investigation, including the development of alkali-activated materials, sustainable cementitious construction materials incorporating a number of different types of wastes, environmental impact assessment, and ecotoxicology.