

Construction and Demolition Waste as Recycled Aggregates in Alkali-Activated Concretes

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Abstract - The growth of global construction has contributed to an inevitable increase in the amount of construction and demolition (C&D) waste, and the recycling of C&D waste as aggregates in concrete is receiving increased interest, resulting in less demand for normal aggregates and bringing a potential solution for the land filling of wastes. Recently, several studies have focused on the use of C&D waste in alkali-activated concrete to move one step closer to sustainable concretes. This paper focuses on the main mechanisms of using C&D waste in the resulting physical, mechanical, and durability properties of alkali-activated concrete in fresh and hardened state properties. The main difficulties observed with recycled aggregates (RA) in concrete, such as high levels of water demand, porous structure, and low mechanical strength, occur in RA alkali-activated concretes. These are associated with the highly porous nature and defects of RA. However, the high calcium concentration of RA affects the binder gel products, accelerates the hardening rate of the concrete, and reduces the flow ability of Alkali-activated concretes. For this reason, several techniques have been investigated for modifying the water content and workability of the fresh matrix and for treating RA and RA/alkali-activated binder interactions to produce more sustainable alkali-activated concretes.

Keywords: alkali-activated concrete; recycled aggregate; construction and demolition waste; sustainability.

1. Introduction

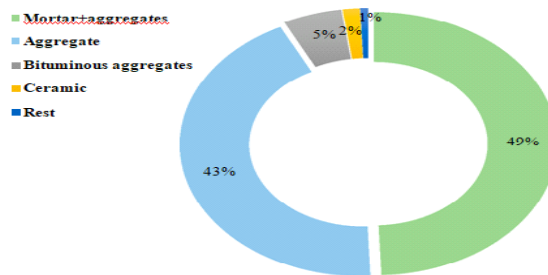
There is an increasing global demand for aggregates in the concrete industry. It is estimated that the global demand for aggregate will rise at an annual rate of about 5.2% and reach 51.79 billion metric tons in 2019. The excessive use of natural aggregates (NA) has raised a growing concern about the depletion of resources and environmental degradation. To tackle this challenge, the use of recycled aggregates (RA) has received significant attention. One of the main sources of RA is construction and demolition (C&D) waste. Based on European legislation of waste management, approximately 850 million tons of C&D waste is generated in the European Union each year, which represents 31% of the total generated waste. However, current estimates show that only 3% of the overall aggregate consumption originates from RA. Based on these estimates, the reuse of this quantity of waste material provides an opportunity to move towards greater sustainability through partial or total replacement of NA in the production of concrete.

C&D waste can contain divergent components, including crushed old concrete from existing concrete structures (either ordinary Portland cement [OPC] or non-OPC based), bricks and stones, fragments from crushed masonry elements, divergent types of ceramics (such as tiles and sanitary ceramics), glasses, and more. This random matrix distribution causes some limitations in the use of these materials with regard to standards for the maximum volume of RA in concrete. For instance, European standards recommend no more than 30 wt % RA in high-strength concrete. Several investigations have been carried out on using C&D wastes as RA in cementations composites. So far, OPC is the main binder used to produce concretes with RA. However, the high rates of production of OPC has been challenged due to its high energy consumption during the calcinations process, excessive quantities of

greenhouse gas (GHG) emissions, depletion of natural resources (in 2017, cement production was 4150 (Mt), and global fossil energy production was around 480 EJ/year), and the generation of dust. These factors have resulted in a high demand for alternative approaches to sustainable concretes.

2. Methodology

Figure displays an estimated RA composition obtained with respect to EN 933–11. Several recycling processes should be implemented with the preparation of C&D waste to use it as RA. As indicated in Figure, the recycling processes include initial inspection, crushing, magnetic separation, and vibrating screens . Following this procedure, the product is mainly NA adhered with cementitious mortar or fragments of hydrated binder. However, there are sources of impurities and contaminants that impact the physical and mechanical properties of RA



2.1 Fresh State Properties

The incorporation of C&D waste as RA in alkali-activated concretes reduces the flowability and accelerates the setting time for the following reasons:

C&D waste is porous and absorbs the liquid phases of the system.

C&D waste is a source of reactive precursors, such as Ca including (1) pre-saturation, and (2) adding additional water during the mixing procedure . Adding additional water during the mixing procedure could have better performance in terms of compensating for the high level of water absorption than a pre-saturation approach. The additional water during the mixing procedure leads to reduced pH values, activator dilution, and compensation for the high level of water absorption in RA. These parameters could significantly affect the fresh and hardened state properties of the compositions; therefore, the content of the added water becomes crucial

2.2 Mechanical Characterizations;

2.2.1 Mechanical Properties

In general, replacing NA with RA degrades the mechanical properties of alkali-activated compositions. Figure 4 shows that replacing NA with RA in different alkali-activated concretes up to 50 wt % had less impact on strength reduction (lower than 20%), while full replacement of NA reduced the final strength more than 50%.

A reduction in the compressive strength of up to 30% has often been reported when NA is fully replaced with RA in cementitious compositions. However, using a slightly larger quantity of cement (~5%) in cementitious

compositions containing RA (fully replacement) resulted in a similar compressive strength and workability as the corresponding quantity of NA.

There are three main concerns with the addition of RA in alkali-activated concretes, as well as in other cementitious materials, as follows:

RA results in low strength due to a porous and cracked structure.

The extra water used in RA reduces the dissolution rate of the aluminosilicate precursors of an alkali-activated matrix.

3. Environmental Analysis

The costs and environmental aspects of all cement and cementless-based compositions for construction depending on the sources and the transportation distance of raw materials. The CO₂ footprint caused by aggregate transportation could reach 20% of total CO₂ emissions, but this value is significantly governed by the amount of aggregate and distance to local sources. Regarding the use of a high ratio of aggregates to other raw materials in concretes, the transportation of aggregates also has a major effect on the final cost of the compositions. Therefore, using recycled C&D waste as aggregates in cementitious concretes and alkali-activated concretes could have superior impacts in terms of financial and environmental aspects.

In terms of environmental analysis, Yang et al. found that the contribution of the binder results in greater CO₂ emissions with OPC concrete, while the contribution of aggregate transportation is more critical in alkali-activated binders. In terms of cost analysis, the type of aggregate has the greatest impact on increasing the total cost of fly ash-based alkali-activated concretes, so that replacing RA with NA increased the material costs in the range of 30–35%.

4. Conclusion

This paper reviewed the effects of the use of C&D waste as RA on fresh and hardened state properties of alkali-activated concretes. This review reflects the considerable amount of research that has been conducted, although some aspects are still unclear and need to be further investigated. In this regard, this study The main elements affecting fresh state properties when using RA could be due to the highly porous nature and subsequent high levels of absorption of liquid phases of the system by RA as well as the availability of reactive precursors in RA, such as calcium. In order to minimize high levels of water absorption with RA, the two approaches that are used are (1) pre-saturation and (2) the addition of more water during the mixing procedure. Using both these techniques leads to reduced pH values, activator dilution, and compensation for the high levels of water absorption with RA. In addition, releasing water from the pre-saturated RA to the matrix could provide internal curing, although the size of RA has a great impact on the efficiency of internal curing conditions and water reservoir in alkali-activated binders. The setting time of alkali-activated concretes containing RA depends on the dominant gel, where the formation of C-A-S-H gel shortens the setting time.

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