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Review on the Importance of Coarse Recycled Concrete Aggregates as Alternative Construction Materials

Anasna Kareem*, Dipak Kumar Sahoo

Cochin University of Science and Technology, Kochi, Kerala, India.

*Corresponding Author Email: anasnacusat22@gmail.com

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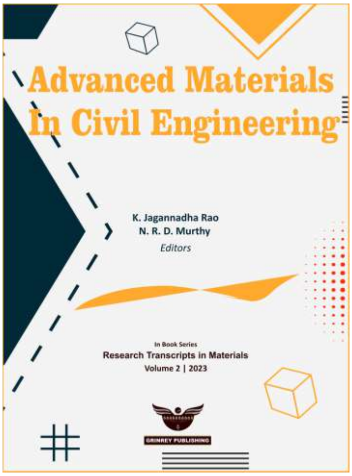

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Abstract
Recycled concrete aggregates are one of the most important supplementary building materials used in the production of "green concrete" or recycled aggregate concrete. They are collected from construction and demolition trash, which decreases construction industry waste (RAC). By size, aggregates are divided into coarse and fine aggregate. Focus of research is on the replacement of coarse aggregate in concrete using coarse recycled concrete aggregate (CRCA). It is vital to provide a major overview on the main developments and advancements in the characterization of CRCA and in the comprehension of the behaviour of concrete containing this, taking into account its varied attributes such as freshness, hardness, and durability. Because of the weak attached

mortar present on its surface, CRCA's performance in all areas falls as the replacement percentage rises. Different treatments such as washing and drying of aggregate, changed mixing sequences, carbonation, slurry and microbiological treatments, CO2 mineralization and air jigging process can mitigate the negative effects of CRCA in the concrete. This study discusses the issues raised by the widespread use of CRCA on concrete and the effectiveness of the numerous treatment solutions that are now available in the industry.

1. Introduction

Increased levels of construction demolition waste (CDW) have a number of negative effects on the environment, including resource depletion, landfill exhaustion, air pollution, noise pollution, and water pollution. In order to address this, numerous years of research have been put into finding new uses for leftover concrete. Concrete crushers are used to create the coarse recycled aggregates, depending on the aggregate size. This article analyzes earlier research on using waste concrete as coarse aggregates, also known as coarse recycled concrete aggregates (CRCA), in place of natural coarse in a variety of applications, including the production of concrete. Concert that consists of recycled concrete is termed as recycled aggregate concrete. Although extensive research on CRCA over the years, its use is still somewhat restricted, especially when it comes to structural and high-grade concrete because of the presence of old attached mortar that has been glued to the surface of aggregates. CRCA is more porous than natural coarse aggregates (NCA) because of the high proportion of pore spaces and the micro structure produced by the attached mortar on the interface (and occasionally in the inter facial transition zone (ITZ)).

Previous research have shown that CRCA's properties can be enhanced using a variety of techniques, including treating recycled aggregate to increase performance and enhancing the binder by fortifying the attached mortar. The extensive reviews and analyses of a few published sources for the maximal replacement of CRCA by NA in structural concrete are presented in this work, along with suggestions to help direct future research. This study examined findings from the preceding two decades that shows how switching from NCA to CRCA considerably affects certain properties.

2. Previous Studies on CRCA and Their Value Addition

2.1 Studies on Properties of CRCA

The impact of Coarse Recycled Concrete Aggregates (CRCA) on green concrete was studied by [1]. According to this investigation, the values for specific gravity and water absorption are 5.23 and 2.03, respectively. According to the studies in [2] and [3], CRCA has a specific gravity that is lower than NCA and ranges between 2.2 and 2.6 under saturated surface dry conditions.

According to [4]'s examination of the durability and strength of recycled aggregate concrete using milled gas as a partial cement replacement, they found that CRCA had a water absorption rate of 4.23%. Different studies on RCA were conducted by [5] , [6] and [7], who also detailed the water absorption characteristics of CRCA and reported that the value is very large compared to the NCA. When compared to NCA, CRCA has a much larger capacity to absorb water because of the attached mortar material that is present on its surface. When concrete is hydrated with water, the water droplets are absorbed by the mortar holding the concrete together instead of settling on the surface of the particles [8].

According to investigations by [1] and [2], the bulk density (kg/m^3) likewise exhibits a lower value than NCA.

According to a study by [9], the ability of concrete to absorb CO2 is significantly influenced by the water content of the mix. These values are impacted by natural carbonation, which depends on the RCA types. The amount of carbonated portlandite present, the effect of RCA's size on gas-to-RCA physical interactions, and the increase in CO2 diffusion at the surface of RCA all have an effect on the amount of carbon dioxide that CRCA can absorb.

2.2 The Impact of CRCA on Fresh Concrete

Considering the investigation by [10], they conducted experiments showing that the slump value falls as the percentage addition of CRCA rises. The use of CRCA in concrete is unlikely to achieve the attribute of fresh concrete, as workability is the primary characteristic of fresh concrete. According to [11] the air volume gain from recycled coarse aggregate increased by 1.1% to 1.7% at 100% replacement but was negligible up to a replacement rate of 60%. A replacement rate of 60% was adequate for the recycled coarse material during the slump tests. The slump values and consistency of freshly produced concrete decrease if the CRCA replacement rate reaches 60%. Due to CRCA's very high water absorption capacity compared to NCA, 5–10% more water was needed for CRCA to achieve a similar level of workability [5].

According to the study by [12] the use of CRCA has virtually no impact on the amount of trapped air in freshly prepared concrete. In fact, some tests have shown a very small increase in the amount of trapped air, up to 1%, which is negligible. The bulk density of concrete having Coarse and Fine Recycled Concrete Aggregate was discovered to be 5% to 10% lower than that of concrete made with natural aggregates. However, concretes having CRCA and fine natural aggregates have a 1% to 5% lower bulk density. The bulk density of new concrete falls as the percentage of recycled aggregate increases in the component aggregate.

The particles in recycled aggregates have a high water absorption rate because of the heterogeneous components in them. Recycled aggregate's less desirable grain form and texture have a detrimental effect on consistency and negatively affect the flow ability of the concrete mixture. The method used to enhance the recycled aggregate's properties before it is combined with the concrete has significant effects on its desired characteristics.

The slump cone test was used in the study by [13], to assess the workability of concrete, and the findings of the experiment showed that the RCA substitution had a considerable impact on the concrete's workability .The resulting concrete, made entirely of untreated recycled aggregate, had a 33-mm slump and was reasonably stiff. The lower workability of RCA is a result of its higher water absorption.

Due to the rough texture of CRCA, RAC demonstrated a larger initial strength growth than NAC, according to [1]. The modest growth rate was lower than NAC.

2.3 Treatments to Improve Fresh Concrete Properties of CRCA

As per [14], for CRCA of 20mm size, the Los Angeles Abrasion (L.A.) treatment, the sodium silicate treatment, and, to a lesser extent, the cement-silica fume treatment were performed. Concrete made with treated recycled aggregates showed much less absorption of water at the larger aggregate size (20 mm) compared to concrete having untreated recycled aggregates of the same size. The LA treatment was the first to obtain the best water absorption performance, and it was subsequently followed by treatments using sodium silicate solutions and cement-silica fume slurries [15]. This considerably strengthened the porous mortar that was sticking. Although the apparent specific gravity of treated aggregate did not vary much, treated aggregate had a lower water absorption rate than untreated CRCA.

According to [16], the use of high range super plasticisers in place of suitable mineral admixtures and aggregate washing can reduce CRCA water absorption. Polymer treatments, according to [17], reduce the water absorption trait of CRCA. This demonstrates how the pore network has developed a polymeric layer and makes it possible for the capacity to absorb water to be significantly reduced. The produced film is effective and alkali-resistant. The amount of polymer-based treatment needed to decrease aggregate's affinity for water. It is extremely beneficial for the ability to hold onto water. Polymer-impregnated-based Recycled Concrete Aggregate (PI-RCA) will be put to the test to see how effectively it maintains the strength of freshly produced concrete.

The properties of the zone around the aggregates (ITZ) may be enhanced when RCA is acid-treated and added to freshly cast concrete using RCA as a base. The micro cracks in this were well responsive to acid therapy, according to the research [18]. These transition zones are more affected on the mortar side by acetic acid treatment than on the other sides. It was also determined that numerous techniques could be used to enhance the properties of RAC's fresh concrete, including chemical treatment, mechanical grinding, carbonation and wrapping, carbonation and calcium meta silicate slurry, warm mix asphalt and hydrated lime, CO2 curing techniques, waste oil and asphalt emulsion, super plasticizers, bio-deposition approach, polymer solution, and silane-based water repellent.

2.4 The Effect of CRCA on Concrete's Hardened & Durability Characteristics

As per [19], the hardened properties and long-term characteristics of concrete were examined using recycled aggregates of varying sizes and compositions. They concluded that substitution of NCA with 25% CRCA reduces 5% elastic modulus and 8% flexural strength. While it increases water absorption by 4% and 70-day drying shrinkage by 12%. So, it is evident that the hardened properties and long-term characteristics of NCA with 25% CRCA are almost similar to but slightly lesser than those of NCA concrete with the same target compressive strength.

In the experimental investigation [20], CRCA was used in place of NCA at 0%, 30%, 50%, 70%, and 100% to determine the hardened properties and long-term characteristics of five different concrete mixes. The findings demonstrated that concrete with replacement percentages of 0% and 30% has substantially equivalent mechanical and durability characteristics to NAC. Concrete may lose some of its bond strength, sorptivity, chloride penetration, absorption, permeability, and compressive strength when an addition exceeds 30%.

After the study conducted by [21], determined the behaviour of RAC in normal strength and high strength concrete. The normalized bond strengths of concrete were highest for normal-strength concrete and lowest for high-strength concrete for levels exceeding 25% RCA replacement. [22] conducted an investigation on two distinct concrete mixes. FRCA (Fine Recycled Concrete Aggregate) was used as the fine aggregate in the first mix, which was made with 100% NCA, and FRCA and 100% CRCA were combined to create the second mix. Two distinct mixes were examined to determine it's strengths against compressive load, flexural load and tensile load; fresh concrete characteristics (workability and density), and durability characteristics (water permeability and carbonation). Except for the 90-day strength against compressive load of concrete mixed with 30% FRCA, the properties of RAC were inferior to those of NAC The performance discrepancy between NAC and RAC does, however, narrow as the curing age is raised. The properties of the concrete were more influenced by the density of RCA than by the water absorption.

The water permeability of recycled concrete was significantly affected by the addition of RCA, which was then impacted by the compressive strength and carbonation level of the concrete.

Total porosity is reduced and the pore structure is improved with less than 25% of CRCA alone or in combination with FRCA. However, the properties decrease as replacement levels rise. According to the study, the splitting tensile strength is increased by the CRCA replacement ratio. Flexural strength is comparable between Conventional Concrete and RAC when using less than 75% replacement [23].

2.5 The Effect of CRCA on Microstructural Properties of Concrete

[24] studied the microstructural properties of RAC using a scanning electron microscope (SEM). They discovered that the addition of Recycled concrete coarse and fine aggregates to self-compacting concrete (SCC) had a negative impact on the mix's microscopic structure, which leads to poorer mechanical properties. The integrity of SCC mixes is enhanced by the inclusion of microsilica, which densifies the pore structure. According to [22], SEM analysis of concretes created with FRCA and CRCA showed significant amounts of macro pores and micro cracks. The study found that for FRCA amounts of 60% and 100%, CRAC has a compact microstructure, whereas at 30% FRCA content, the opposite occurs.

In the study [25], presoaked CRCA underwent an accelerated carbonation process. They performed mechanical testing on the concrete, such as compressive, splitting tensile, and flexural strength tests, and micro-property tests, such as Vickers micro-hardness (VMH), X-ray diffraction, and scanning electron microscope-energy dispersive spectroscopy (SEM-EDS). The findings demonstrated that calcite had been inserted into the old mortar (OM) and ITZ pores in the CRCA, improving the CRCA's characteristics.

2.6 Treatments to Enhance Coarse Recycled Aggregate Concrete's Hardened and Durability Characteristics (CRAC)

[10] performed tests on washed CRCA to evaluate the characteristics of CRAC and came to the conclusion that after washing, properties improve as a result of the elimination of weak and porous adhering mortar. After being exposed to carbon dioxide for 28 days, concrete employing natural and washed CRCA showed no signs of carbonation. When 100% of

washed CRCA is replaced by NCA, Rapid Chloride Penetration Test (RCPT) results reveal a modest level of concrete permeability.

According to the study by [16], the techniques used to lower the detrimental effects of deformation in CRAC are as follows: TSMA (two-stage mixing approach); (ii) application of high-range superplasticizers; and (iii) substitution of suitable mineral admixtures. The hardened and long span charecteristics of CRAC were enhanced by adopting the EMV (Equivalent Mortar Volume) approach along with TSMA, which makes the ITZ of concrete denser and lowers the overall porosity.

According to [26], one sort of thorough treatment approach for mortar removal and reinforcing is an acetic acid solution. The external reinforcement of the RAC structure using fibre and gel materials was done in order to fill the microstructural cracks and pores and to improve the shrinkage resistance of the RAC. Fibre-reinforced polymer materials have the potential to considerably improve a structure's hardening properties.

Structural concretes with a typical strength of 30 MPa and the ability to linearly lower global warming potential, according to [23]. [27] asserts that the resistance to compression load, flexural load and tensile load of RAC made from superior CRCA concretes with strengths greater than 50 MPa remain unaffected. We can infer that the strength of the original concrete affects the properties of RAC. RAC with reduced elastic modulus and inferior hardened properties is produced from low to moderate strength primary or original concrete. According to [28], air jigging process promoted a reduction in the amount of mortar and ceramics in RCA and increased the amount of rock in RCA thus reduced water absorption, and increased the resistance to compression load of concrete.

Particle shaping will enhance the long span properties of RAC and the quality of CRCA, as claimed [29].To improve the properties of concrete, the old adherent mortar of the CRCA needs to be removed and improved. The durability can be increased by carbonation treatment of CRCA, adopting an efficient mixing method for the RAC mixture, grading the CRCA, and adding nanomaterial.

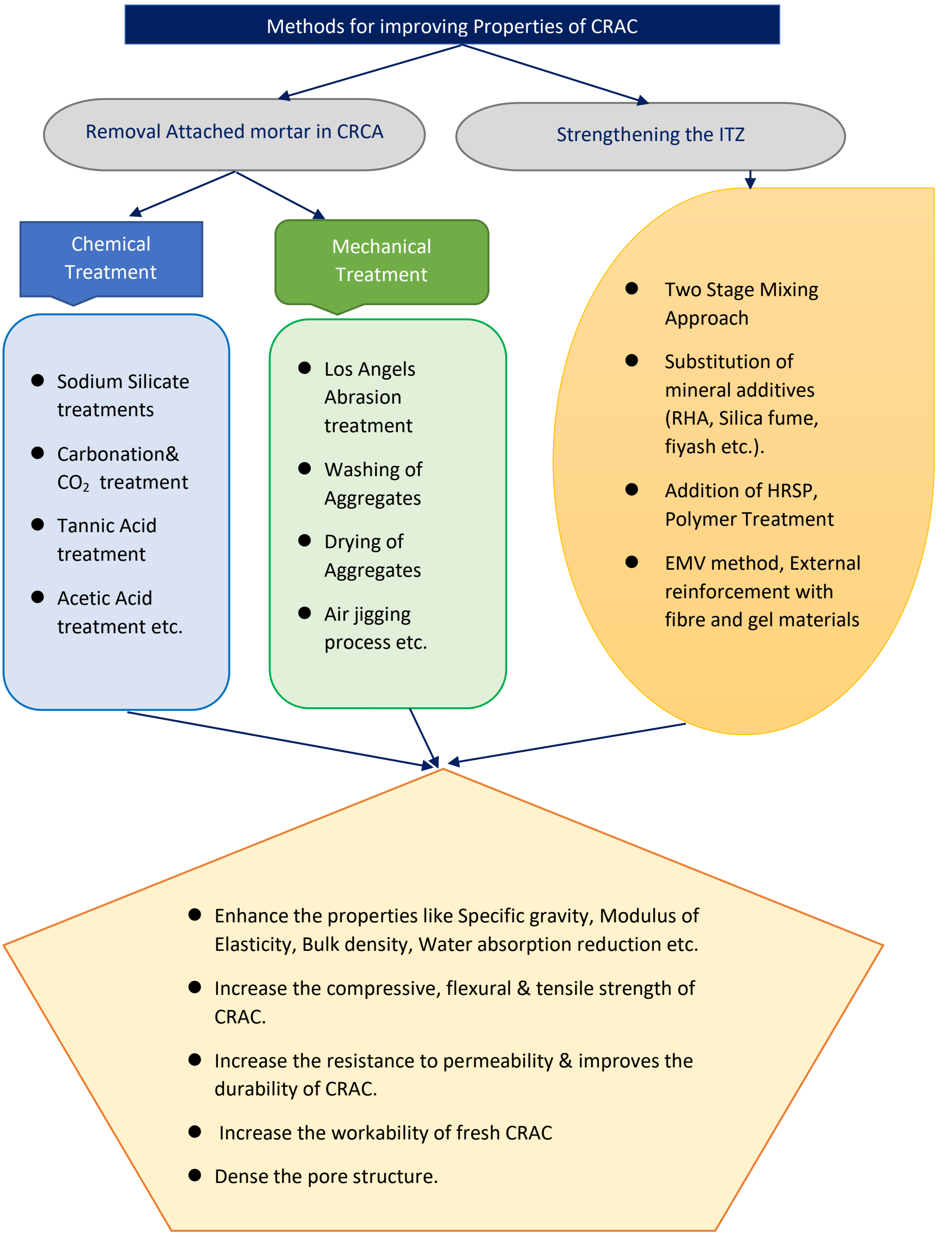

Fig. 1. Methods of improving the properties of CRCA

3. Conclusion

- There have been numerous studies done on the use of CRCA, and many more are under way. The paper analyses research done on concrete-based CRCA characteristics. Prior research's experimental findings were examined in order to utilise recycled coarse aggregates in concrete manufacturing. The outcomes of the research are as follows:
- The origin of RCA and quality control have been determined to be important aspects in determining the quality of concrete made from recycled aggregates, according to numerous studies. However, more investigation is required to evaluate the effectiveness of RCA treatment techniques and to ascertain the overall performance of concrete generated from C&D waste.
- The fresh, hardened, and durability properties of concrete decreased with each percentage addition of CRCA in place of NCA. The fundamental cause of the increased water absorption and consequently greatly diminished workability of CRCA is the attached mortar that is present in the recycled aggregates.Many techniques are available to improve the quality of CRCA such as:
    - washing and drying of CRCA,
    - changed mixing sequences,
    - carbonation, slurry & microbiological treatments,
    - CO2 mineralization,
    - air jigging.
- The best design strength for recycled aggregate concrete that is used as structural concrete is 30 MPa. The majority of research advised substituting NCA with CRCA in structural concrete up to 30% without jeopardising its hardness and durability properties.
- It is possible to add high range super plasticizers in the concrete to achieve workability while reducing the high water absorption features of CRCA.
- Less dense concrete has a higher parent concrete grade. Due to the rich adhering mortar's higher absorption, the water absorption increased along with the parent concrete's enhanced richness.

- The use of RCA for High performance concrete and high strength concrete was investigated with the addition of mineral admixtures, thermo-mechanical treatment of the RCA, and other procedures, and yielded successful results.
- Since the microstructural properties show the compactness of concrete, they directly indicate its strength. The densification of the pore structure of RAC can be achieved by accelerated carbon treatment of CRAC and the addition of polymers and fibres to concrete.

The review study makes it abundantly evident that recycled concrete aggregate may be utilised to produce sustainable concrete. However, more investigation is required to apply RCA outside of the lab.

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