

Evaluation of Workability and Moisture Transport Properties of Recycled Concrete Aggregate

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ABSTRACT

The growing generation of construction and demolition waste has encouraged the use of recycled concrete aggregate (RCA) as a sustainable alternative to natural aggregates in concrete production. However, concerns remain regarding its effect on workability and durability-related properties. This study investigates the influence of partial replacement of natural coarse aggregate with RCA on the workability and moisture transport properties of concrete. Concrete mixes were prepared with varying RCA replacement levels, and fresh concrete behavior was evaluated using slump and slump loss tests. Moisture transport characteristics were assessed through water absorption and sorptivity tests at different curing ages. The results show that increasing RCA content leads to a noticeable reduction in workability and workability retention due to the higher water absorption and rough surface texture of RCA. In addition, water absorption and sorptivity increased with higher RCA replacement, indicating greater susceptibility to moisture ingress. Nevertheless, mixes containing low RCA replacement levels (5–10%) demonstrated performance comparable to conventional concrete. The study concludes that limited RCA usage can be effectively adopted to promote sustainable concrete construction without significantly compromising performance.

Keywords: Recycled concrete aggregate, Slump loss, Water absorption, Sorptivity, Moisture transport

INTRODUCTION

The construction industry plays a vital role in infrastructure development, but it is also one of the largest contributors to construction and demolition waste. A substantial portion of this waste consists of concrete, which places increasing pressure on landfill capacity and accelerates the depletion of natural aggregate resources. To address these environmental concerns, Recycled Concrete Aggregate (RCA) has emerged as a promising alternative to natural aggregates in concrete production, supporting more sustainable construction practices (Silva et al., 2020; Xiao et al., 2022). Despite its environmental advantages, the widespread use of RCA in concrete remains limited due to concerns about its influence on concrete performance. Unlike natural aggregates, RCA typically contains adhered old mortar, higher porosity, and greater water absorption capacity. These characteristics can negatively affect the workability of fresh concrete and increase moisture transport properties such as water absorption and sorptivity, which are closely linked to durability (Poon & Chan, 2006; Kou & Poon, 2012). Increased moisture ingress can accelerate deterioration mechanisms such as reinforcement corrosion and reduce the long-term service life of concrete structures (Neville, 2011). Although numerous studies have investigated RCA concrete, there is still uncertainty regarding the extent to which different RCA replacement levels influence workability and moisture transport behavior. Variations in material sources, mix proportions, and testing conditions have resulted in inconsistent findings across the literature, highlighting the need for controlled experimental studies (Tam et al., 2021; Wang et al., 2023). Therefore, this study aims to evaluate the effect of partial replacement of natural coarse aggregate with RCA on the workability and moisture transport properties of concrete. Particular emphasis is placed on slump behavior, water absorption, and sorptivity to assess the suitability of RCA for practical concrete applications and to contribute to the effective use of recycled materials in sustainable construction. In recent years, the growing volume of construction and demolition waste has intensified research into the reuse of RCA as a sustainable construction material. Several studies confirm that while RCA contributes positively to environmental conservation, its physical properties—such as higher porosity and residual mortar, significantly influence concrete performance (Silva et al., 2020; Tam et al., 2021; Xiao et al., 2022). Workability has been consistently identified as one of

the most affected fresh concrete properties. Researchers have reported reductions in slump with increasing RCA content due to the higher water absorption and rough surface texture of RCA particles, which increase internal friction within the mix (Kisku et al., 2020; Limbachiya et al., 2021; Li et al., 2022). Studies further indicate that workability loss becomes more severe at higher replacement levels unless mix modifications or admixtures are used (Thomas et al., 2021; Pedro et al., 2022). Moisture transport properties, particularly water absorption, have been widely studied as key indicators of durability. Concrete incorporating RCA generally exhibits higher water absorption than conventional concrete, mainly due to the porous nature of the adhered old mortar and microcracks present in RCA particles (Guo et al., 2021; Tang et al., 2022). Although extended curing can slightly reduce absorption through continued hydration, the overall trend remains higher for RCA concrete (Poon et al., 2020; Bravo et al., 2021). Sorptivity has gained increasing attention as a measure of capillary water uptake. Research consistently shows that RCA concrete exhibits higher sorptivity than natural aggregate concrete, indicating increased vulnerability to moisture ingress and aggressive agents (Kou & Poon, 2020; Zhang et al., 2021; Wang et al., 2023). Higher sorptivity values are often linked to weaker interfacial transition zones and interconnected pore structures within RCA concrete (Zhu et al., 2022).

METHODOLOGY

This study adopted an experimental approach to investigate the effect of RCA on concrete workability and moisture transport properties. Ordinary Portland Cement was used as the binder, along with natural fine aggregate and coarse aggregate. RCA was sourced from crushed waste concrete, cleaned to remove impurities, and used as a partial replacement for natural coarse aggregate. Prior to mix preparation, key physical properties of the RCA, including specific gravity and water absorption, were determined.

Concrete mixes were prepared with varying RCA replacement levels of 0% (Control), 5%, 10%, 15% and 20% while maintaining a constant water–cement ratio to ensure consistency. All materials were mixed using a laboratory concrete mixer to achieve uniformity. Workability was evaluated using the slump test immediately after mixing. For moisture transport assessment, specimens were cast, cured in water for up to 28 days, and oven-dried before conducting water absorption and sorptivity tests in accordance with standard procedures.

Analysis and Results

Table 1: Workability of Concrete with RCA Replacement

RCA Replacement (%)	Slump (mm)
0% (Control)	74
5%	67
10%	61
15%	54
20%	47

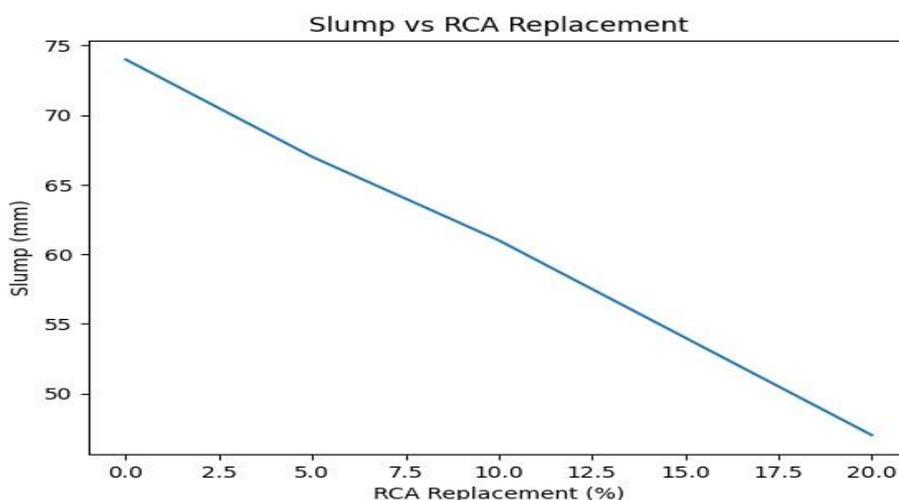


Figure 1: slump against RCA Replacement

Workability results as seen in table 1 and figure 1 indicate a consistent reduction in slump with increasing RCA content. The control mix exhibited the highest slump value, while mixes incorporating RCA showed progressively lower workability, reaching the lowest value at 20% replacement. This reduction can be primarily attributed to the physical characteristics of RCA, including its angular shape, rough surface texture, and the presence of adhered old mortar. These features increase internal friction and absorb a greater amount of mixing water, thereby reducing the free water available to enhance flowability (Poon & Chan, 2006; Kou & Poon, 2012). Similar trends have been widely reported in the literature, confirming that RCA tends to reduce fresh concrete workability unless specific mix modifications are adopted (Qasim et al., 2024; Memon et al., 2023).

Table 2: Slump loss over time

RCA Replacement (%)	Initial (0 min)	30 min	60 min
0% (Control)	74	67	61
5%	71	63	57
10%	69	60	54
15%	54	50	46
20%	47	43	41

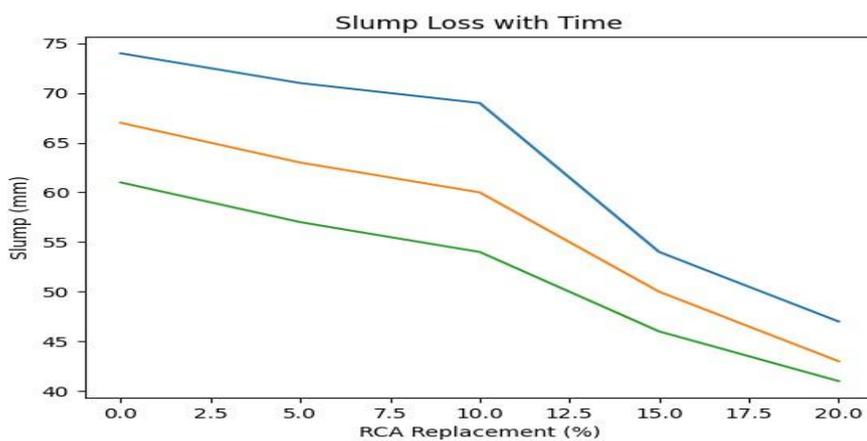


Figure 2: Graph of slump loss with time

The evaluation of slump loss over time as depicted in table 2 and figure 2 further highlights the negative influence of RCA on workability retention. Although all mixes experienced a reduction in slump over the 60-minute period, mixes containing higher RCA proportions exhibited a more pronounced loss. This behavior is largely associated with the continuous absorption of water by the porous old mortar attached to RCA particles, which progressively stiffens the concrete matrix as time elapses (Tam et al., 2007). The accelerated slump loss observed at higher RCA contents suggests that workability control becomes increasingly challenging in practical applications, particularly where extended transport or placement times are involved.

Table 3: Water absorption

RCA Replacement (%)	7 Days	14 Days	28 Days
0% (Control)	3.2	3.4	3.6
5%	3.5	3.0	3.8
10%	3.6	3.8	3.9
15%	3.5	3.6	3.5
20%	3.7	3.9	4.0

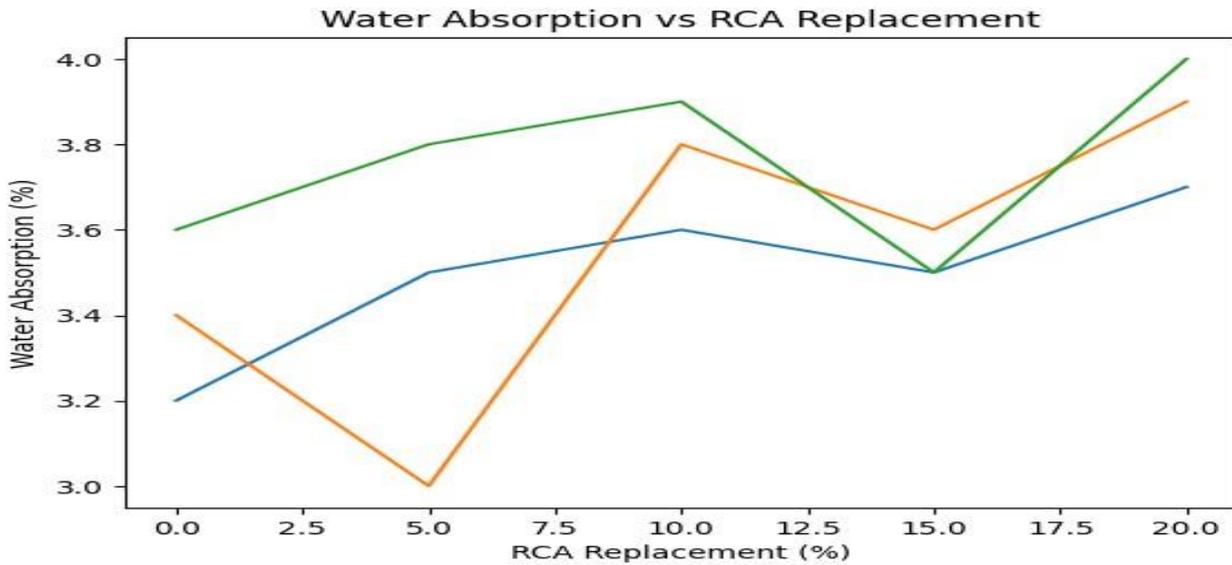


Figure 3: Graph of water absorption vs RCA replacement

Moisture transport properties were also significantly influenced by RCA replacement. Table 3 and figure 3 clearly depicted how water absorption values increased with both curing age and RCA content, with higher replacement levels consistently exhibiting greater absorption than the control mix. The elevated absorption can be attributed to the higher porosity and microcracked structure of RCA, which increases the overall pore connectivity within the concrete matrix (Neville, 2011; Silva et al., 2014). While extended curing promotes continued hydration and partial pore refinement, it does not fully offset the intrinsic porosity introduced by RCA. These findings align with previous studies that identify water absorption as a critical durability concern for RCA-based concrete, particularly at higher replacement levels (Kou & Poon, 2012).

Table 4: Sorptivity

RCA Replacement (%)	Sorptivity
0% (Control)	0.11
5%	0.13
10%	0.16
15%	0.19
20%	0.21

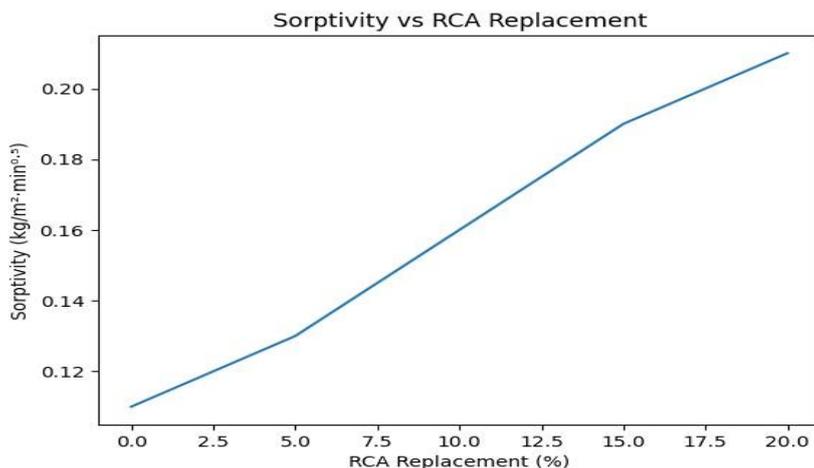


Figure 4: Graph of Sorptivity and RCA replacement

Sorptivity results show in in table 4 and depicted in graph 4 followed a similar trend, increasing steadily with higher RCA replacement percentages. The control mix demonstrated the lowest rate of capillary water uptake, whereas the 20% RCA mix showed nearly double the sorptivity value. Increased sorptivity indicates enhanced capillary suction and a higher susceptibility to moisture ingress, which is often linked to weaker interfacial transition zones and interconnected pore structures associated with RCA (Kou & Poon, 2012; Wang et al., 2023). Elevated sorptivity may accelerate the penetration of aggressive agents such as chlorides and sulfates, potentially compromising long-term durability

Table 5: Summary of Results

RCA Replacement (%)	Slump (mm)	Slump Loss (0 min)	Slump Loss (30 min)	Slump Loss (60 min)	Water Absorption (7 Days)	Water Absorption (14 Days)	Water Absorption (28 Days)	Sorptivity (kg/m ² ·min ^{0.5})
0% (Control)	74	74	67	61	3.2	3.4	3.6	0.11
5%	67	71	63	57	3.5	3.0	3.8	0.13
10%	61	69	60	54	3.6	3.8	3.9	0.16
15%	54	54	50	46	3.5	3.6	3.5	0.19
20%	47	47	43	41	3.7	3.9	4.0	0.21

Despite these performance reductions, the results in table 5 indicate that RCA can be incorporated at lower replacement levels without causing significant deterioration in concrete properties. Mixes containing 5–10% RCA exhibited moderate reductions in workability and acceptable increases in water absorption and sorptivity when compared to the control mix. This suggests that limited RCA substitution can achieve sustainability objectives while maintaining satisfactory performance, provided that appropriate mix design strategies and quality control measures are implemented. Overall, the findings confirm that while RCA contributes positively to sustainable construction practices, its proportion must be carefully controlled. Excessive RCA replacement leads to notable reductions in workability and increased moisture transport, which may adversely affect durability. However, when used at lower replacement levels, RCA presents a viable alternative to natural aggregates, supporting resource conservation without substantially compromising concrete performance

The radar chart in figure 5 provides a holistic view of how increasing levels of recycled concrete aggregate (RCA) influence both the fresh and durability-related properties of concrete. Each axis on the chart corresponds to a specific performance parameter, namely slump, slump loss at 0, 30, and 60 minutes, water absorption at 7, 14, and 28 days, and sorptivity. The closed shapes formed on the chart represent different RCA replacement levels (0%, 10%, and 20%), allowing direct visual comparison of overall performance at each replacement level. A greater outward extension along any axis indicates a higher value of the corresponding property. From the radar plot, a clear reduction in fresh concrete performance is observed as the RCA content increases. The axes associated with slump and slump loss progressively contract with higher RCA replacement, indicating reduced initial workability and a faster loss of consistency over time. This behavior reflects the higher water absorption and rougher surface texture typically associated with RCA. In contrast, the durability-related parameters show the opposite trend. The axes representing water absorption and sorptivity expand outward with increasing RCA content, highlighting greater porosity and enhanced moisture transport within the concrete matrix. This suggests that higher RCA levels facilitate easier ingress of water due to the presence of adhered old mortar and microcracks. The 0% RCA mix exhibits the most favorable performance, characterized by superior workability and the lowest moisture transport properties. Conversely, the 20% RCA mix shows a pronounced inward shift for workability parameters and an outward expansion for absorption and sorptivity. This contrasting pattern effectively illustrates the trade-off between incorporating RCA for sustainability and maintaining optimal fresh and durability performance of concrete.

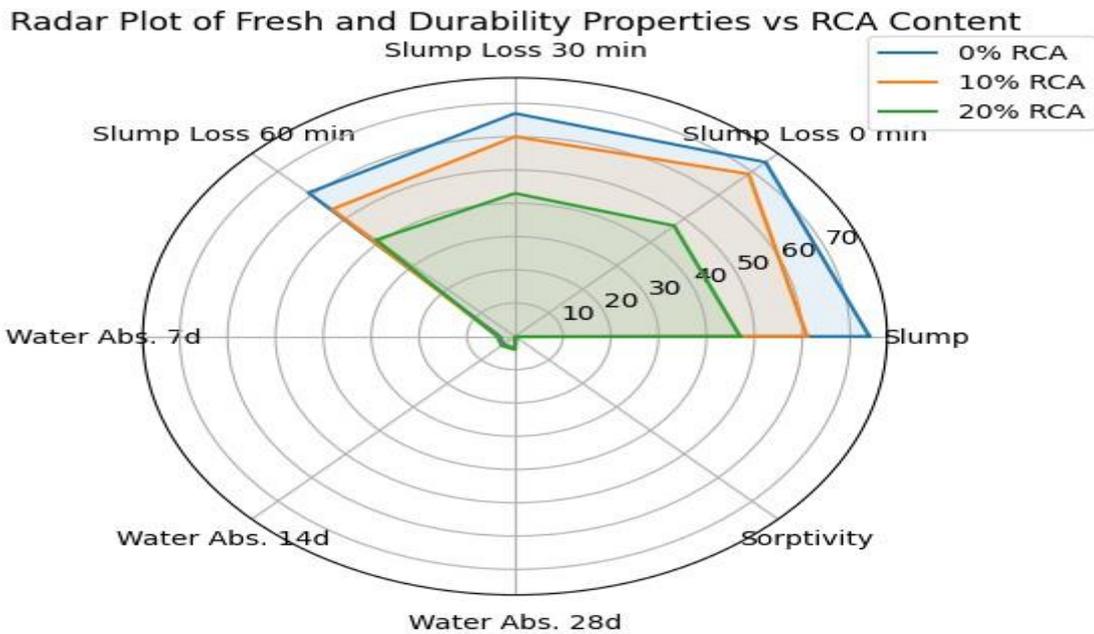


Figure 5: Radar plot of fresh and measured durability properties and RCA content

CONCLUSION AND RECOMMENDATIONS

The findings of this study demonstrate that the incorporation of recycled concrete aggregate (RCA) significantly influences both the workability and moisture transport properties of concrete. As RCA replacement increased, a consistent reduction in slump and higher slump loss over time were observed, indicating reduced workability and workability retention. These effects were primarily attributed to the high water absorption capacity, angular shape, and rough surface texture of RCA particles. In addition, moisture transport properties, including water absorption and sorptivity, increased with higher RCA content, reflecting a more porous concrete matrix and weaker interfacial transition zones compared to the control mix. Despite these reductions in performance, mixes containing low RCA replacement levels (5–10%) exhibited behavior comparable to the control concrete, with only moderate reductions in workability and acceptable increases in water absorption and sorptivity. This suggests that limited RCA replacement can be effectively utilized in concrete production without significantly compromising fresh and hardened concrete properties, while still offering environmental benefits through reduced natural aggregate consumption and waste recycling. Based on the results, it is recommended that RCA replacement be restricted to lower percentages when workability and durability-related properties are critical design considerations. Proper mix design adjustments, such as water control and aggregate pre-treatment, are essential to mitigate the adverse effects associated with RCA use.

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