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A Review paper on Durability Studies on Construction and Demolition Waste Material

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Abstract
The global rise in construction and demolition (C&D) waste generation presents significant challenges and opportunities for sustainable construction practices. This study examines the durability performance of concrete made by replacing 30% of natural coarse aggregates with recycled coarse aggregates derived from C&D waste. The research aims to evaluate the feasibility of using recycled materials in structural applications by conducting a series of durability tests, including assessments of resistance to freeze-thaw cycles, sulfate attack, chloride ion penetration, and carbonation.
Concrete specimens incorporating 30% recycled coarse aggregates were prepared and tested, and their performance was compared to that of conventional concrete. The results indicate that while there is a noticeable impact on certain mechanical and durability properties, the modified concrete exhibited acceptable performance under specific conditions. Strategies for enhancing the durability of recycled aggregate concrete, such as incorporating supplementary cementitious materials, were also investigated. The findings suggest that partial replacement of coarse aggregates with recycled materials can be a viable solution for sustainable construction, provided that appropriate mix design adjustments are made. This research contributes to understanding the long-term behavior of recycled aggregate concrete and provides a basis for developing guidelines for its use in various construction applications.
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Introduction

The construction industry is one of the largest consumers of natural resources, significantly impacting the environment through resource depletion, energy consumption, and waste generation. Construction and demolition (C&D) waste, which includes materials such as concrete, bricks, wood, metal, and gypsum, contributes substantially to the global waste stream. The proper management and utilization of this waste have become critical concerns in achieving sustainable development goals and reducing the environmental footprint of the construction sector.

One promising approach to managing C&D waste is its use as recycled aggregate in concrete. The recycling of C&D waste not only conserves natural aggregate resources but also reduces the environmental impact associated with waste disposal and raw material extraction. However, despite these potential benefits, the use of recycled aggregates in concrete poses several challenges. The variability in the quality of recycled aggregates and their generally inferior properties compared to natural aggregates can affect the performance and durability of concrete. These concerns have limited the widespread adoption of recycled aggregate concrete (RAC) in structural applications, making it essential to comprehensively evaluate its long-term behavior and performance.

This thesis focuses on the partial replacement of natural coarse aggregates with recycled coarse aggregates at a 30% replacement level to assess the feasibility of using RAC in durable construction applications. Specifically, the study investigates key durability properties, including resistance to freeze-thaw cycles, sulfate attack, chloride ion penetration, and carbonation. By understanding the impact of recycled coarse aggregates on concrete durability, the research aims to develop strategies to enhance the performance of RAC and provide insights into its practical use in sustainable construction practices.

The objectives of this study are threefold: (1) to characterize the mechanical and durability properties of concrete with 30% recycled coarse aggregate, (2) to compare the performance of RAC with conventional concrete, and (3) to propose methods to improve the durability of RAC using supplementary cementitious materials and optimized mix designs. The research outcomes will contribute to advancing sustainable construction practices and promoting the responsible use of recycled materials in the built environment

Literature review

The study employs standard testing protocols, such as ASTM C39/C39M, to evaluate the compressive strength of recycled aggregate concrete with varying rates of large-size recycled coarse aggregates (LRCA). Additionally, flexural strength (ASTM C78/C78M) and tensile strength (ASTM C496/C496M) tests are conducted to assess the concrete's response to bending and tension, offering a comprehensive view of its mechanical performance. By systematically adjusting the LRCA replacement rates, the study aims to establish a predictive relationship between LRCA rate and compressive strength, using statistical methods like regression analysis to validate trends. Quality control measures for the recycled aggregates, including pre-tests for size distribution and impurities, are also implemented to ensure the reliability of results.(1)

Studies show that incorporating recycled coarse aggregate (RCA) generally reduces the compressive strength of concrete due to RCA's higher porosity and weaker bonding with the cement matrix. Higher RCA content affects mechanical properties, often decreasing durability compared to natural aggregate concrete. In seismic applications, increased RCA ratios can reduce ductility and energy dissipation, impacting structural resilience. However, at optimal RCA levels, improvements are seen in flexural load capacity of beams, enhancing load distribution. RCA content also influences load-deflection behavior, which is crucial for serviceability. Therefore, while RCA can lower certain strengths, careful proportioning can yield sustainable and structurally viable concrete.(2)

Your study on recycled aggregate concrete (RAC) investigates its mechanical properties, focusing on how varying recycled aggregate replacement ratios impact strength. Large-size recycled coarse aggregates (LRCA) are analyzed to understand their effect on RAC's compressive strength. The study establishes conversion relationships for different strength indices to better compare RAC performance with traditional concrete. Practical formulas for calculating the elastic modulus are developed, which will assist engineers in material selection and design. By quantifying the relationship between LRCA rate and compressive strength, the research aims to enhance the use of recycled materials in sustainable construction. Financial support is provided by the National Natural Science Foundation. (3)

The literature review analyzed 60 publications on recycled concrete aggregates (RCA) over 32 years (1990–2022). Studies focused on RCA from construction and demolition waste, emphasizing mechanical properties and durability. Research highlighted factors such as compressive strength, tensile strength, and elasticity of RCA in concrete. Keywords like "recycled aggregate concrete," "mechanical properties," and "durability" guided the search. Findings showed that RCA's quality and mix proportion significantly affect concrete performance. Replacement ratios and RCA types were compared to determine optimal use in structural applications. Data revealed trends and challenges in applying RCA in sustainable construction. (4)

This study focuses on Compressed Trommel Fine Blocks (CTFBs), aiming to explore their mechanical properties and durability, areas scarcely covered in existing research. Unlike conventional recycled aggregates from construction and demolition waste, trommel fines have received limited attention as building materials. We examine CTFBs made with varying trommel fine ratios, investigating their compressive strength, elastic modulus, and potential structural applications. Durability assessments will include tests for water absorption, freeze-thaw resistance, and chemical resistance. The study aims to establish practical formulas linking CTFB composition to mechanical performance, providing foundational insights for future sustainable construction materials. (5)

Construction and demolition waste (CDW) is widely used in construction applications, but it generally provides lower strength than natural aggregates. Its high CaO content allows CDW to neutralize acids, a beneficial property in environments where pH control is essential. This makes CDW a promising candidate for Cemented Paste Backfill (CPB) in mining, aiding in CPB management through acid neutralization. Despite this potential, research on using CDW as a mining backfill material is limited. Further studies could assess CDW's effectiveness and durability in mining backfills, expanding its applications beyond construction and supporting sustainable mining practices. (6)

This study examines the effects of recycled concrete aggregate (RCA) on compressive strength, a critical factor in sustainable construction. Concrete waste poses significant environmental issues due to its non-biodegradable nature, prompting interest in recycling it. Findings reveal that compressive strength tends to decrease as RCA replacement rates rise, highlighting the importance of RCA quality on concrete performance. Silica fume admixtures, through pozzolanic reactions, effectively improve the strength of recycled aggregate concrete, partially compensating for the strength reduction. Enhanced RCA quality is shown to mitigate performance loss, suggesting a pathway to optimize recycled concrete for structural applications.(7)

The review identifies several techniques to enhance recycled aggregate concrete (RAC) durability. Key methods include surface treatments like silica fume or nano-silica coatings, which improve aggregate bonding and reduce water absorption. Incorporating pozzolanic materials such as fly ash and ground granulated blast-furnace slag (GGBS) was noted to enhance both chloride and frost resistance. Adjustments in mix design, such as optimizing the water-cement ratio, also improve impermeability and strength. Thermal and mechanical pre-treatments were highlighted for removing old mortar adhered to aggregates, boosting overall aggregate quality. The review emphasizes that these methods address key durability concerns, supporting RAC's wider adoption in structural applications.(8)

The paper presents a detailed review of over 300 studies on recycled aggregate concrete (RAC), with an emphasis on 126 recent articles from the past five years. It categorizes various strengthening methods, including nano-modification, fiber reinforcement, and surface treatment of recycled aggregates, which are among the most effective techniques. The review highlights how nano-modification enhances interfacial bonding, while fiber reinforcement improves tensile strength and crack resistance. Studies show surface treatments, such as coating or soaking recycled aggregates, increase compressive strength and durability by minimizing micro-cracks. These methods, tested across Australia, Brazil, and China, underscore regional advancements in RAC technology and provide foundational insights for practical applications in sustainable construction.(9)

The study addresses sustainability in concrete production by investigating recycled aggregates from construction and demolition waste, focusing on mechanical properties and practical issues. It compares recycled and natural aggregates, assessing differences in durability and load-bearing capacity. The study highlights challenges such as variable quality and limited acceptance in the industry. Testing various replacement ratios, it examines effects on compressive strength, durability, and elasticity. Future research will focus on the load-carrying capacity of recycled aggregates. Ultimately, the findings aim to support sustainable construction practices and reduce reliance on natural aggregates, aligning with eco-friendly building initiatives.(10)

The review explores the mechanical properties of recycled aggregate concrete (RAC), drawing on experimental data from over 40 years of global literature. It highlights key parameters such as the water-cement ratio and aggregate content, which significantly affect the concrete's properties. Findings show that as recycled aggregate content increases, the compressive strength of RAC tends to decrease. Additionally, there is a direct correlation between the elastic modulus and compressive strength in RAC, suggesting that strength characteristics can predict stiffness. The review also aims to establish practical relationships between these properties, aiding in the use of recycled aggregates for sustainable construction. It examines RAC's load-carrying capacity and compares the properties of recycled versus natural aggregates, addressing sustainability issues and application challenges. (11)

Your study addresses the global issue of solid waste generation in cities, with a focus on Construction and Demolition (CD) Waste. This type of waste contributes significantly to environmental challenges. By using recycled aggregates, the strength and load capacity of concrete can be enhanced, offering a sustainable alternative to traditional building materials. Environmental awareness is driving the reuse of construction materials, promoting sustainability in the construction industry. Government initiatives, policies, and regulations are supporting recycling efforts, ensuring that the construction sector becomes more sustainable. Recycled aggregates not only reduce waste but also conserve natural resources. The study explores the benefits of using these materials in concrete, highlighting their mechanical properties and durability. Ultimately, it aims to foster a more circular economy within the construction industry. (12)

Construction and demolition (CD) waste primarily consists of surplus and damaged materials from construction activities. Over the past two decades, there have been significant international efforts to address and improve the management of CD waste. In India, CD waste represents about 33% of the total solid waste generated, highlighting its considerable contribution to the overall waste stream. The European Waste Catalogue classifies CD waste into eight distinct categories, providing a structured approach to its management. To estimate the amount of CD waste generated, the Waste Generation Rate (WGR) is a critical metric that helps in waste forecasting and planning. Various models have been developed to quantify CD waste, most of which are based on volume measurements. The potential for reusing materials, such as bricks, depends on factors like the age of the building being demolished, as older buildings may provide materials in better condition for reuse. These factors are essential for designing effective waste management strategies, as they influence both the amount of waste generated and the potential for material recovery. The growing awareness of the importance of CD waste management reflects the ongoing efforts to minimize its environmental impact and maximize the reuse of materials. (13)

The literature review explores different methods used to assess the performance of construction and demolition waste management (CDWM). It delves into various research approaches and data collection techniques, highlighting the diverse ways in which CDWM performance is evaluated across studies. The review identifies key indicators that are critical for assessing the effectiveness of CDWM, such as material recovery rates, waste diversion, and environmental impacts. These indicators are essential for understanding the success of waste management strategies and for improving overall system efficiency. Additionally, the review points out gaps in the existing literature, revealing areas where further research is needed to enhance the understanding and implementation of CDWM practices. Based on these findings, the review proposes a comprehensive framework for assessing CDWM performance, aimed at filling these gaps and providing a structured approach to evaluating waste management systems. This framework seeks to address the limitations identified in current studies and offer a more robust method for assessing CDWM, ultimately contributing to better decision-making and more sustainable waste management practices in the construction industry. (14)

Conclusion

This study investigated the durability performance of concrete made with 30% replacement of natural coarse aggregates (NCA) by recycled coarse aggregates (RCA) sourced from construction and demolition (C&D) waste. A series of durability tests, including , sulfate attack, chloride ion penetration, and carbonation, were conducted to evaluate the feasibility of using recycled aggregates in sustainable construction practices. Based on the experimental results and analysis, the following conclusions are drawn:

Sulfate Attack Resistance: The resistance of RAC to sulfate attack was lower than that of conventional concrete, showing greater expansion and deterioration over time. The use of supplementary cementitious materials (SCMs) was effective in mitigating these effects and enhancing sulfate resistance

Acid resistance test

The acid resistance test showed that recycled aggregate concrete (RAC) has lower durability in acidic environments. RAC exhibited greater mass loss and strength reduction than conventional concrete. Surface erosion was more severe in RAC due to higher porosity and microcracks. Using supplementary cementitious materials (SCMs) improved RAC's acid resistance. RAC may be suitable for less acidic conditions, but protective measures are needed for aggressive environments. Further research is required to enhance acid resistance in RAC

Chloride resistance: The chloride resistance test revealed that concrete with 30% recycled coarse aggregates (RCA) has higher chloride ion permeability than the control mix with natural coarse aggregates (NCA). This increased permeability raises the risk of corrosion for embedded steel reinforcement. To address this issue, incorporating supplementary cementitious materials (SCMs) and applying surface treatments are recommended. These strategies can help improve the durability of recycled aggregate concrete (RAC) in chloride-rich environments. Overall, optimizing the mix design is crucial for ensuring the long-term performance of RAC

Saturated water absorption: The results of the water absorption test reveal differences in permeability between conventional concrete (0% replacement) and concrete with 30% replacement of coarse aggregates by recycled aggregates. Conventional concrete exhibited an average weight increase of 5.07% after water immersion, indicating higher water absorption compared to the 30% replacement concrete, which showed a lower average weight increase of 3.83%.

The reduced water absorption in the 30% recycled aggregate concrete suggests that it may possess a relatively denser matrix or fewer permeable voids, potentially due to the compaction or packing effect of the recycled aggregates. This improvement in water absorption performance highlights the viability of incorporating recycled aggregates for enhancing the durability of concrete, particularly in environments prone to water exposure. However, further studies are needed to correlate these findings with long-term durability under various environmental conditions

Abrasion resistance test: In terms of compressive strength, conventional concrete experienced an average strength reduction of 46.7% after the test, whereas the 30% replacement concrete showed a considerably higher average strength loss of 77.5%. This suggests that the incorporation of recycled aggregates adversely affects both abrasion resistance and the ability to retain structural strength under abrasive conditions. These findings emphasize the need for optimized mix designs or surface treatments to improve the wear resistance and durability of recycled aggregate concrete in high-abrasion applications.

RCPT test: The table compares the charge passed over time for conventional concrete (ACC) and recycled coarse aggregate concrete (RCC) with 30% replacement. ACC specimens show a steady increase in charge passed, indicating progressive hydration or aging effects. In contrast, RCC specimens stabilize after 90 minutes, with minimal changes beyond 120 minutes, suggesting altered hydration or pore structure due to recycled aggregates. This stable conductivity profile may indicate differences in durability and ion migration compared to conventional concrete. The findings highlight potential impacts of recycled aggregates on concrete performance.

Sorptivity Test: The sorptivity test results show that replacing 30% of natural coarse aggregate with recycled coarse aggregate in concrete (ACC) improves water absorption resistance compared to conventional concrete (A CC). ACC exhibits lower sorptivity values (0.00761–0.00796) than A CC (0.00901), indicating better durability due to enhanced packing density or altered pore structure. Fully recycled aggregate concrete (RAC) has slightly higher sorptivity values (0.00784–0.00872) than ACC but remains comparable to or slightly better than A CC, reflecting intermediate performance. These findings suggest that partial replacement of natural aggregates with recycled materials is an effective way to reduce water absorption and enhance concrete durability.

Water permeability test: The table presents the depth of penetration (in mm) values for conventional concrete (ACC-0) and recycled coarse aggregate concrete (ARC-30), with 30% coarse aggregate replacement, in a water permeability test. The results indicate that the depth of penetration for ARC-30 (recycled coarse aggregate concrete) is generally higher compared to ACC-0 (conventional concrete) in all six measurements. The average depth of penetration for ARC-30 is 3.5 mm, which is significantly greater than the 1.6 mm average for ACC-0. This suggests that the incorporation of 30% recycled coarse aggregates increases the permeability of the concrete, likely due to the higher porosity and potential microcracks in the recycled aggregates, which facilitate easier water infiltration. Consequently, ARC-30 exhibits reduced resistance to water ingress compared to conventional concrete, which may impact its durability, particularly in environments where water penetration is a concern.

Residual strength: The table presents the residual compressive strength of conventional concrete (R-0%) and concrete with 30% replacement of coarse aggregates (R-30%) after exposure to varying temperatures. For both concrete types, the residual strength decreases as the temperature increases. Conventional concrete (R-0%) experiences a significant decline in strength from 35.74 MPa to 15.89 MPa as the temperature rises from room temperature to 600°C. In contrast, concrete with 30% recycled coarse aggregate (R-30%) shows an initial drop in strength from 29.14 MPa to 18.51 MPa at 600°C, but notably, at 200°C, the strength of R-30% actually increases to 42.13 MPa, surpassing that of R-0%. This behavior suggests that the recycled aggregate concrete may have some beneficial thermal properties at moderate temperatures, but as the temperature rises further, the strength of both concrete types decreases significantly. This indicates that the inclusion of 30% recycled aggregates does not significantly enhance the thermal performance of concrete but may exhibit specific advantages under certain conditions, such as at lower temperatures

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