A Study on Performance Evaluation of Lightweight Concrete utilizing Industrial by-products and Recycled Aggregates

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Abstract— **This study delves into the thorough performance assessment of lightweight concrete, enriched with industrial by-product fly ash and recycled aggregates across a spectrum of compositions. The integration of these alternative materials holds substantial promise for sustainable construction, aiming to mitigate environmental impacts and promote resource efficiency. The study begins by outlining the rationale for incorporating fly ash and recycled aggregates into lightweight concrete mixes, particularly for the purposes of enhancing mechanical properties while concurrently addressing environmental concerns. The research entails a systematic variation of fly ash content from 0% to 30%, alongside a constant 20% content of recycled aggregates as coarse aggregate. The concrete specimens formulated with these diverse compositions then undergo a battery of comprehensive tests, focusing on compressive, split tensile, and flexural strengths. These evaluations provide critical insights into load-bearing capacities, resistance to tension, and ability to withstand bending forces. The meticulous analysis of test results offers nuanced understanding regarding the impact of varying fly ash proportions on concrete performance. By specifically concentrating on compressive, split tensile, and flexural strength tests, the study provides valuable insights into how the combined influence of fly ash and recycled aggregates influences the concrete's mechanical behaviour. The outcomes highlight that the incorporation of fly ash within a certain range yields improvements in the lightweight concrete's mechanical properties. However, exceeding the optimal proportion of fly ash might lead to diminishing returns, potentially affecting overall strength. These findings guide the establishment of practical composition ranges, assisting engineers in formulating environmentally responsible concrete mixes that concurrently ensure structural performance. The significance of this research extends widely.**

Index Terms—Lightweight concrete, industrial by-products, fly ash, recycled aggregates, compressive strength, split tensile strength, flexural strength, sustainable construction, resource efficiency, mechanical properties, environmental impact

I. INTRODUCTION

The construction industry plays a pivotal role in the development of societies and economies, but it also exerts significant pressure on the environment through the consumption of natural resources and the generation of waste. In the pursuit of sustainable and environmentally responsible construction practices, there is a growing emphasis on the development and utilization of innovative construction materials. This introduction sets the stage for an exploration of lightweight concrete, a versatile and eco-friendly construction material that has gained prominence due to its reduced environmental footprint and unique characteristics. Lightweight concrete, as the name suggests, is characterized by its lower density compared to conventional concrete, making it an appealing choice for a wide range of applications. It embodies the principles of sustainability by conserving resources, reducing energy consumption, and minimizing waste. The motivations for the adoption of lightweight concrete are multifaceted. Sustainability is a driving force in contemporary construction, with an increasing demand for materials that lessen the depletion of natural resources and mitigate environmental harm. Lightweight concrete aligns with these objectives, offering reduced material consumption and enhanced energy efficiency. Moreover, its lower weight simplifies transportation and handling, potentially leading to cost savings and improved construction efficiency. The structural performance of lightweight concrete can be engineered to meet the specific needs of a project, making it a versatile choice for architects and builders seeking innovative solutions. Incorporating industrial by-products and recycled aggregates into lightweight concrete takes its environmental benefits a step further. Materials such as fly ash, slag, recycled concrete, and recycled glass, which would otherwise end up in landfills, become valuable components of sustainable construction. By reducing waste and conserving resources, these materials not only contribute to the ecological well-being of the planet but also demonstrate cost- effectiveness. Some industrial by-products possess pozzolanic properties, further enhancing the material's performance, and recycled aggregates can augment its properties when used thoughtfully. This approach to lightweight concrete aligns seamlessly with the principles of the circular economy, where materials are reused and repurposed, promoting a more sustainable and responsible construction industry. The performance evaluation of lightweight concrete that utilizes industrial by-products and recycled aggregates is the central focus of this exploration.

II. LITERATURE SURVEY

Muhammad Faisal Junaid et al provided an overview of the current state of research, highlighting the existing gaps, challenges, and potential solutions regarding the utilization of waste byproducts from various industries in Lightweight Concrete (LWC). It identifies key factors governing the incorporation of waste byproducts in LWC, whether as materials, admixtures, or a combination thereof. The assessment of a waste material's suitability for use in LWC hinges on these factors. Despite numerous studies, there remains a need for further characterization of various waste materials for their application in LWC. Additionally, there's a call for evaluating and mitigating the potential hazardous impacts of waste byproducts in LWC, as well as emphasizing durability and conducting life cycle assessments for waste-based LWC. The paper's goal is to offer insights beneficial to researchers and practitioners engaged in construction, waste management, sustainable development, resource conservation, and recycling fields.

Vali, K.S. and Murugan gave an overview of the current research landscape, focusing on gaps, challenges, and potential solutions in utilizing waste byproducts from diverse industries in Lightweight Concrete (LWC). It outlines pivotal factors governing how waste byproducts are integrated into LWC, whether as materials, admixtures, or in combination. The evaluation of a waste material's suitability for LWC relies on these factors. Despite numerous studies, there's still a need for further characterizing various waste materials to enhance their applicability in LWC. Additionally, there's a call to assess and mitigate potential hazards posed by waste byproducts in LWC, while also emphasizing durability and conducting life cycle assessments specific to waste-based LWC. The paper aims to provide valuable insights for researchers and practitioners involved in construction, waste management, sustainable development, resource preservation, and recycling sectors.

The study conducted by Nahla Hilal, Mohammed Freeh Sahab, and Taghreed Khaleefa Mohammed Ali in July 2021 focused on exploring the use of walnut shells (WS) as a replacement for coarse aggregate in the production of self-compacting concrete (SCC). The research aimed to assess the fresh and hardened properties of lightweight self-compacting concrete (LWSCC) incorporating varying volumes of WS as a sustainable alternative to natural aggregates.Self-compacting concrete (SCC) has gained attention in construction due to its ability to enhance durability, reduce bleeding, and effectively bond with reinforcement bars. However, a significant amount of aggregates is typically required in SCC production. The study aimed to investigate the potential of utilizing walnut shells, an agricultural waste material, as a substitute for traditional aggregate in SCC formulations, thus promoting eco-friendly building materials.Ten different volume fractions of walnut shells ranging from 5% to 50% were employed as replacements for coarse aggregate in the SCC mixes, with increments of 5%. The research evaluated the fresh and hardened properties of SCC for all mixes, including a control mix without walnut shell substitution. The findings indicated a general decrease in all tested properties as the volume fraction of walnut shells increased. However, the study revealed that LWSCC could be achieved with a walnut shell volume fraction equal to or greater than 35%. At a 35% ratio of WS, specific desirable properties were obtained, such as a slump flow diameter (SFD) of 560 mm, a compressive strength of 35 MPa, and a bond strength of 6.55 MPa.These results suggested that incorporating walnut shells as a replacement for coarse aggregate in SCC led to a reduction in certain properties with increased substitution percentages. However, at higher volume fractions of walnut shells (specifically 35%), the LWSCC still exhibited favorable properties, demonstrating its potential as a viable and sustainable alternative in concrete production while maintaining acceptable performance levels.

The research conducted by Abdulsamee M. Halahla, Mohammad Nadeem Akhtar, and Amin H. Almasri in March 2019 explored the feasibility of utilizing demolished waste, particularly concrete remains, as coarse aggregate in new concrete mixes. The demolition of concrete structures worldwide generates substantial quantities of waste, presenting opportunities to repurpose these materials as coarse aggregates for new concrete formulations. Numerous structures, reaching the end of their service life or not meeting contemporary standards, necessitate removal, resulting in large amounts of concrete debris. Repurposing this waste not only conserves landfill space but also promotes sustainability by minimizing reliance on natural resources.The study's primary objective was to investigate the viability of integrating old recycled concrete as coarse aggregate in new concrete mixes and assess its impact on the evolution of compressive strength. Core samples obtained from demolished concrete structures underwent testing to ascertain their compressive strength, serving as indicators of aggregate properties for the new concrete mixes. Subsequently, cubes and cylinders were cast using the new recycled aggregate concrete (RAC), allowing for experimental determination of compressive strength and splitting tensile strength.The findings revealed that the evolution of compressive strength in recycled aggregate concrete exhibited behavior similar to concrete incorporating natural aggregate, albeit with values approximately 10% lower. Moreover, the study observed that the water absorption rate of recycled aggregate was notably higher compared to that of natural aggregate, suggesting the need for adjustments in mix design considerations.Overall, the research suggested the potential feasibility of employing recycled concrete as coarse aggregate in new concrete mixes, despite the slightly reduced compressive strength compared to concrete utilizing natural aggregate. However, the higher water absorption of recycled aggregate highlights the importance of modifying mix designs to compensate for this disparity. This study underscores the possibilities of sustainable waste management and resource optimization by repurposing demolished concrete waste, contributing to both environmental conservation and the advancement of sustainable construction practices.

III. METHODOLOGY FOR EXPERIMENTS

FinenessTest:

The provided procedure outlines the steps for conducting the fineness test on cement using a 90 µm sieve. This test is crucial to determine the particle size distribution of cement, particularly measuring the amount of fine particles present.

Apparatus:
1. IS Sieve (90 µm) with lid.
2. A balance with 0.01 gm sensitivity.
3. A pure bristle or nylon brush.
4. Sieve Shaking Machine (optional).

Procedure: Take a 1000 grams (1 Kg) sample of cement for the test (designated as w1). Break up any lumps and ensure the cement particles are well-distributed within the sample. Transfer the 1 Kg cement sample into the sieve and securely close it with the sieve lid. If available, place the sieve in a sieve shaking machine and operate it for 15 minutes. If a machine is not accessible, manually shake the sieve thoroughly in all directions for a minimum of 15 minutes. Gently brush the sieve base using the bristle brush to ensure all cement particles pass through the sieve. Weigh the amount of cement retained on the sieve after sieving and record it as w2. Calculate the percentage of cement retained on the 90 µm sieve using the formula: Percent of cement retained on sieve = (w2 / w1) x 100.

Limitation: As per the Indian Standard, the amount of cement retained on the 90 µm sieve should not exceed 10%. This limitation is crucial as it indicates the fineness of the cement and adherence to quality standards.

This test and its limitation are essential to ensure that the cement meets the required quality specifications, particularly concerning its fineness, which can significantly impact concrete properties and performance in construction applications.

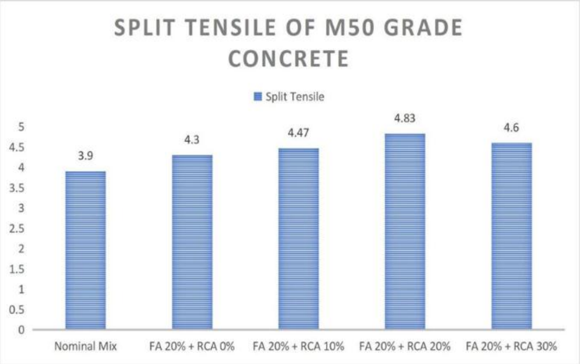
SPLIT TENSILE

Retrieve the wet specimen from the water at the desired curing age (e.g., 7 days, 28 days) for estimating tensile strength. Wipe off any excess water from the surface of the specimen. Mark diametrical lines on both ends of the specimen to ensure they are on the same axial plane. Record the weight and dimensions of the specimen. Set up the compression testing machine within the required range for testing. Place a plywood strip on the lower plate of the testing machine and position the specimen on it. Align the specimen so that the marked lines on the ends are vertical and centered over the bottom plate. Position another plywood strip above the specimen. Lower the upper plate gently until it lightly touches the plywood strip. Apply the load continuously and steadily, without sudden impact, at a controlled rate within the recommended range (0.7 to 1.4 MPa/min or 1.2 to 2.4 MPa/min according to IS 5816:1999). Finally, record the breaking load (P) when the specimen fails under tension.

IV. RESULTS AND DISCUSSIONS

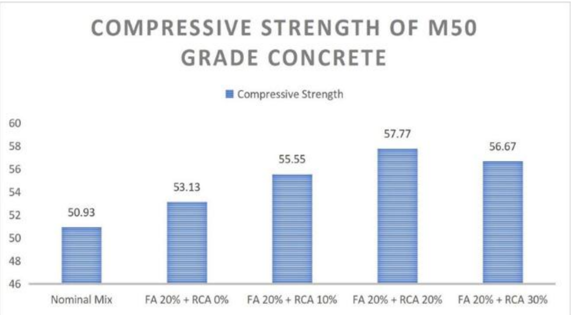
SPLIT TENSILE

From the above results we observed that increase in compressive strength of M50 grade concrete with 20% RCA with the additionof 20% of Fly Ash was observed to be 1.10%, 1.15% and 1.24%respectively when compared with plain concrete.



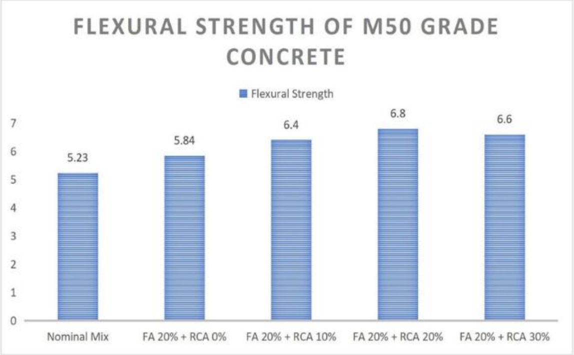
COMPRESSIVE STRENGTH

From the above results we observed that increase in compressive strength of M50 grade concrete with 20% RCA with the additionof 20% of Fly Ash was observed to be 1.04%, 1.09% and 1.13%respectively when compared with plain concrete.



FLEXURAL STRENGTH

From the above results we observed that increase in compressive strength of M50 grade concrete with 20% RCA with the additionof 20% of Fly Ash was observed to be 1.12%, 1.22% and 1.30%respectively when compared with plain concrete.



V. CONCLUSIONS

1. Effect of Fly Ash: Incorporating 20% Fly Ash in M50 grade concrete exhibited a consistent trend of enhancing compressive, flexural, and split tensile strengths across various compositions.
2. Compressive Strength Improvement: The addition of 20% Fly Ash to M50 concrete with 20% Recycled Aggregate (RCA) showed an average increase of approximately 1.09% to 1.13% in 7-day to 28-day compressive strengths compared to plain concrete.
3. Flexural Strength Enhancement: M50 concrete with 20% RCA and 20% Fly Ash displayed an average increase of about 1.22% to 1.30% in 7-day to 28-day flexural strengths compared to plain concrete.
4. Split Tensile Strength Augmentation: The addition of 20% Fly Ash in M50 concrete with 20% RCA exhibited an average increase of approximately 1.15% to 1.24% in 7-day to 28-day split tensile strengths compared to plain concrete.
5. Fly Ash and RCA Synergy: Combining 20% Fly Ash with 20% RCA in M50 concrete produced a synergistic effect, demonstrating an overall improvement in mechanical properties over plain concrete.
6. Recycled Aggregate Influence: Gradual incorporation of RCA from 0% to 30% in M50 concrete revealed a positive impact on strength properties, with maximum benefits observed at 20% RCA content.
7. RCA Optimization: The 20% replacement of natural aggregates with RCA demonstrated

optimal enhancement in strength characteristics without compromising the concrete's performance.

8. Age-Dependent Strength: With curing time, the 28-day strengths consistently improved compared to 7-day strengths across all compositions, indicating ongoing concrete maturity and strength development.
9. Feasibility of RCA and Fly Ash Blend: The combination of RCA and Fly Ash in M50 concrete showed promise in improving concrete's mechanical properties, which can be advantageous for sustainable construction practices.
10. Importance of Supplementary Cementitious Materials: The utilization of supplementary materials like Fly Ash presents potential benefits in enhancing concrete strength, demonstrating the significance of sustainable alternatives in concrete production.

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