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Analysing the Mechanical Characteristics of Concrete Incorporating Recycled Fine Aggregates from Construction Demolition Waste

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Abstract

The exploitation of natural resources and the increasing concerns about maintaining the balance of the environment have sparked an interest in seeking alternative materials for use in construction, with a particular focus on the production of concrete. This study examines the potential of replacing natural sand with recycled fine aggregate (RFA) obtained from waste generated by construction and demolition activities. By conducting a series of comprehensive experiments, the research evaluated various mechanical properties of concrete, including its compressive strength, tensile strength, and flexural strength. The investigation followed a methodical approach, adjusting the proportions of RFA in the concrete mixtures to identify the optimal replacement ratio that ensures both the structural integrity and overall performance of the concrete.

Introduction

Concrete, a fundamental component widely used in construction, is recognized for its significant environmental influence, mainly due to its high requirement for natural resources, especially sand, and its substantial contribution to carbon emissions. Consequently, an increasing amount of research has concentrated on devising environmentally friendly alternatives that can mitigate the ecological consequences of concrete manufacturing. In this context, the use of recycled fine aggregate as a substitute for natural sand in concrete has emerged as a promising approach to tackle both environmental concerns and the scarcity of resources. The diminishment of natural resources, combined with the accumulation of waste from construction and demolition, has emphasized the urgent necessity to explore sustainable options. Recycled fine aggregate, obtained from crushed concrete, provides a practical solution to reduce reliance on natural resources, thereby effectively lessening the environmental pressure connected with traditional sand extraction. By reusing construction waste, the integration of recycled fine aggregate not only lessens the strain on landfills but also presents a feasible method to encourage the circular economy within the construction domain. This paper aims to thoroughly investigate the mechanical feasibility of incorporating recycled fine aggregate in concrete, focusing particularly on evaluating its effects on various mechanical parameters. Notably, the mechanical performance of concrete, encompassing compressive strength, tensile strength, and flexural strength, will be meticulously assessed to demonstrate the potential of recycled fine aggregate as a substitute for natural sand. Through a critical evaluation of the mechanical properties of concrete containing recycled fine aggregate, this research endeavours to provide empirical proof that can aid informed decision-making in the construction sector, encouraging a move towards more sustainable and environmentally conscious practices. The outcomes of this study are expected to make a significant contribution to the ongoing discussion on sustainable construction materials and act as a driver for the widespread adoption of recycled fine aggregate in concrete production, thereby promoting a more sustainable and ecologically aware approach to the development of infrastructure.

Materials Used

Cement: Ordinary Portland Cement (OPC) of grade 43 having fineness of 4%, consistency of 28%, initial and final setting time of 78 minutes and 393 minutes respectively and specific gravity of 3.15 was used for the project.

Fine Aggregates: Fine aggregate conforming to IS 383:1970 having specific gravity of 2.64, water absorption of 1.11% and conforming to Zone I were used.

Coarse Aggregates: Aggregates of nominal size of 20mm, having specific gravity of 2.65, water absorption of 0.45% and impact value of 16.76% were used for the project.

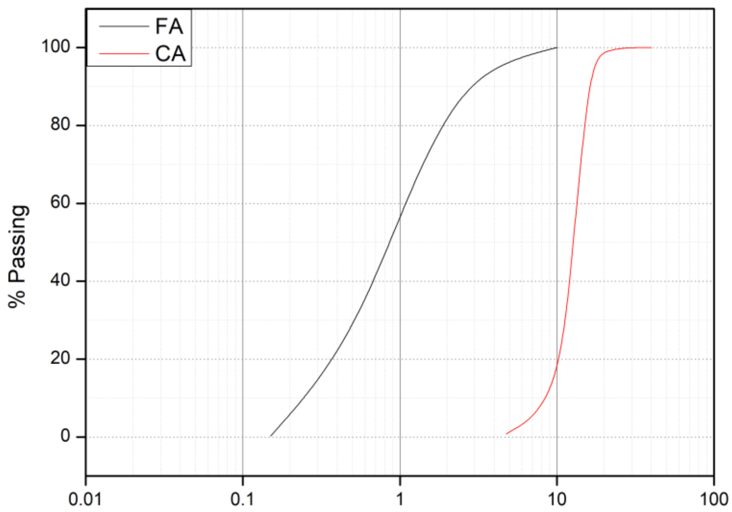


Fig. 1- Particle size distribution of natural fine and coarse aggregate.

Recycled Fine Aggregates: Crushed concrete aggregates passing through IS sieve of 4.75mm having specific gravity of 2.59, water absorption of 1.83% and conforming to Zone II were used.

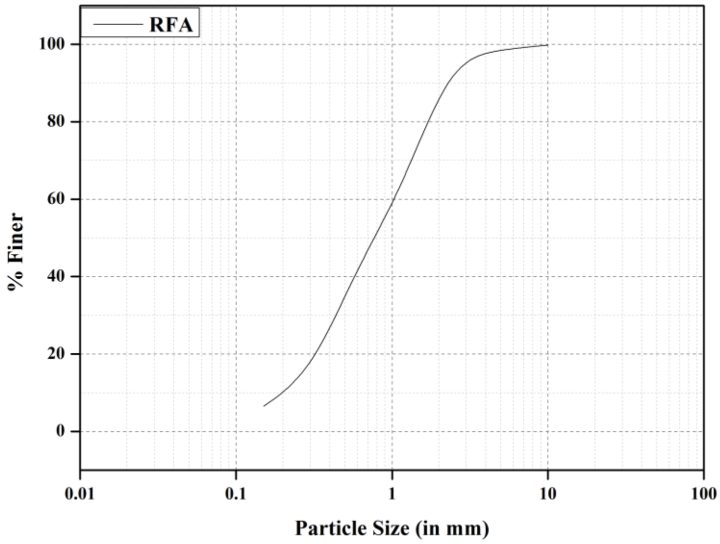


Fig.2- Particle Size distribution of RFA.

Methodology

The methodology involves the following steps:

1) **Materials:** Collect the materials required for the preparation of concrete, including cement, sand, and recycled fine aggregate.
2) **Preliminary Tests:** Perform various preliminary tests on the materials to determine different physical parameters.
3) **Mix Design:** Prepare the mix design of M30 grade concrete and prepare samples of concrete for varying proportions of recycled fine aggregate (10%, 20%, 30%, 40%, and 50%).
4) **Mechanical Tests:** Perform mechanical tests on the concrete after curing to determine its compressive strength, split tensile strength, and flexural strength. Compare the results with M30 grade conventional concrete.

Sample Preparation

Three samples were prepared for each test (i) Cubes of size 150mmX150mmX150mm were prepared to determine compressive strength. (ii) Cylinders of diameter 100mm and length 200mm to determine tensile strength (iii) Beams specimen of size 150mmX150mmX700mm were prepared to determine flexural strength of concrete. Table1 illustrates nomenclature of samples prepared.

NCA (in %)	RCA (in %)	NFA (in %)	RFA (in %)	Nomenclature
100	0	100	0	CWRFA-1
100	0	90	10	CWRFA-2
100	0	80	20	CWRFA-3
100	0	70	30	CWRFA-4
100	0	60	40	CWRFA-5
100	0	50	50	CWRFA-6

Table 1- Nomenclature of samples prepared.

Results

Compressive strength

The compressive strength of concrete specimens with varying levels of Recycled Fine Aggregate (RFA) replacement, compared to a standard mixture categorized under grade M30 and denoted as CWRFA-1, at intervals of 7, 14, and 28 days were evaluated. The findings indicated that certain mixtures, namely CWRFA-2, CWRFA-3, and CWRFA-4, experienced improvements in strength at different stages of the experiment with increment percentages of 0.82%, 2.34%, and 0.52%, 6.32%, 5.62%, and 6.11%, and 9.43%, 8.18%, and 7.20%, respectively. However, increasing the proportion of RFA beyond a certain level resulted in a decline in strength, as evidenced by reductions of 5.53%, 14.72%, and 12.76% for CWRFA-5 at 7, 14, and 28 days, respectively. Furthermore, CWRFA-6 experienced a substantial decline in strength, recording decrements of 11.28%, 24.61%, and 23.40% at 7, 14, and 28 days, respectively.

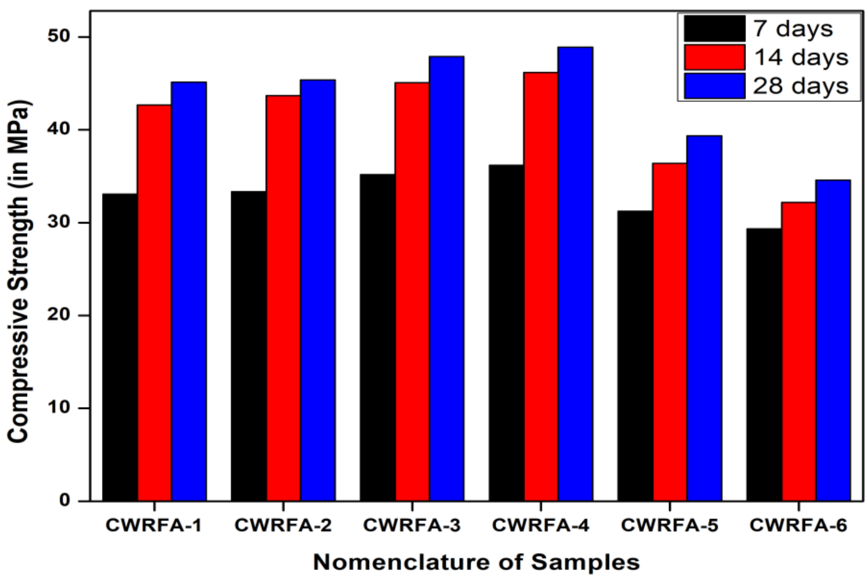


Fig.3- Compressive Strength of Concrete.

Split Tensile Strength

The tensile strength of a cylinder specimen at durations of 7, 14, and 28 days were tested and were compared to the CWRFA-1. Notably, the results showed that CWRFA-2 exhibited an increase in tensile strength of 6.13%, 3.55%, and 12.96% for the respective curing periods. CWRFA-3 demonstrated a substantial improvement, with an increase in tensile strength of 11.93%, 7.10%, and 13.89% over the 7, 14, and 28-day periods. In comparison to CWRFA-1, CWRFA-3 displayed a significant increase in strength by 20%, 9.89%, and 24.76% for the specified curing timeline. However, further increases in the percentage of RFA resulted in a decline in tensile strength. Specifically, CWRFA-5 exhibited a decrease of 13.55%, 13.70%, and 9.03% over the designated curing duration. Furthermore, CWRFA-6 demonstrated a more substantial decrease of 19.03%, 23.60%, and 28.07% at the 7, 14, and 28-day periods respectively.

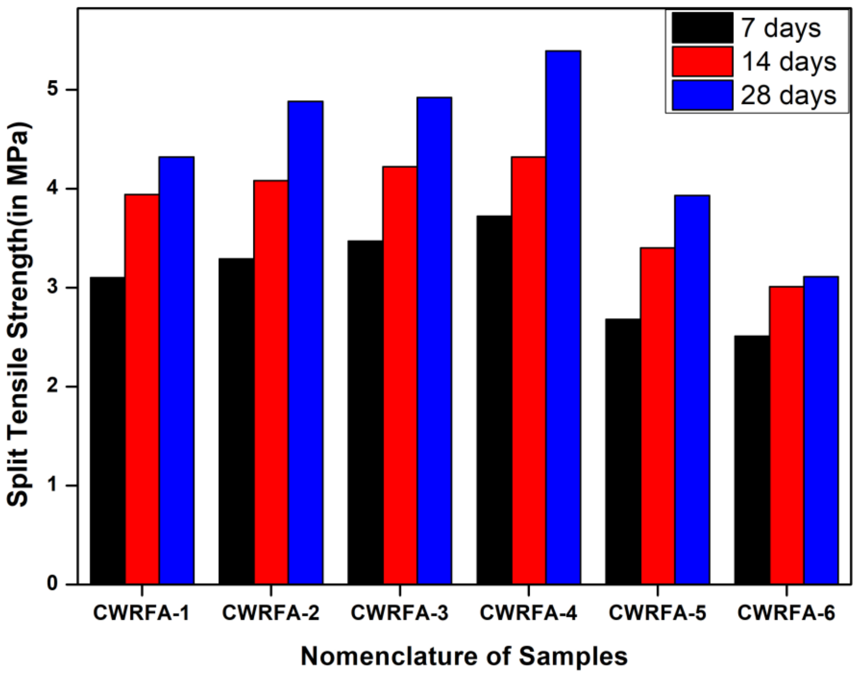
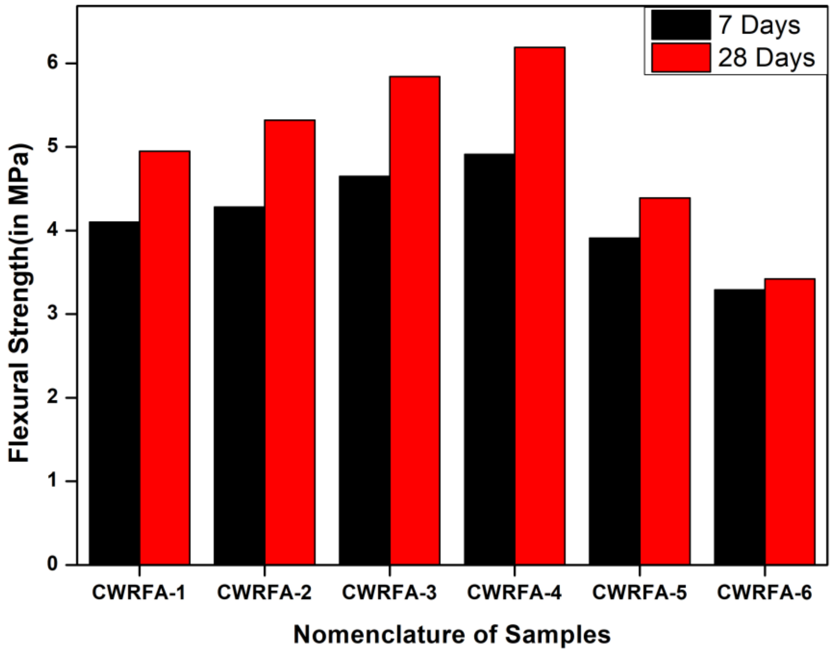


Fig.4- Split Tensile Strength of Concrete.

Flexural Strength

The aim of this study was to assess the flexural strength of beams after 7 and 28 days of curing, and compare the results to CWRFA-1. The 7- and 28-day strength of CWRFA-1 was found to be 4.10 MPa and 4.95 MPa respectively. The findings revealed that the flexural strength of concrete increased up to CWRFA-4, with an improvement ranging from 4% to 20% after 7 days of curing, and approximately 7% to 25% after 28 days. However, further increases in the proportion of RFA resulted in a decline in strength, by 6% to 24% after 7 days of curing and 11% to 32% after 28 days.



Conclusions

This study aimed to evaluate the effect of the proportion of recycled fine aggregate (RFA) on the strength of concrete. The conclusions of the study are as follows:

- Concrete prepared with RFA up to a replacement level of 30% showed a nominal enhancement in compressive strength of approximately 1% to 7%. However, a further increase in the level of RFA resulted in a decline in the strength by 20% to 28% for a 28-day curing period.
- Tensile strength of concrete showed an improvement of 12% to 24% for replacement levels of RFA up to 30%. Beyond this level, any increase in RFA resulted in a decline in strength by 9% to 30% for a 28-day curing period.
- Flexural strength also showed an increase of about 7.5% to 25% for up to a 30% replacement level of RFA. However, beyond this level, there was a decline in strength of 11% to 32% for a 28-day curing period.
- These findings suggest that while the use of RFA can potentially enhance the strength of concrete, there is an optimal percentage of RFA that should be considered to ensure good concrete performance in terms of compressive, tensile, and flexural strength.

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