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Determining the Characteristics of Concrete Composed of Different types of Aggregates

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Abstract

This study investigates the influence of recycled aggregates on the compressive strength of concrete designed for medium workability. Various replacement proportions of recycled aggregates (0%, 50%, 60%, and 100%) were examined using conventional mix design methods, specifically focusing on 10 mm recycled aggregates' impact. The specimens comprised 100% recycled aggregate, with a combination of 60% 20 mm and 40% 10 mm sizes. Compressive strength analyses were conducted at 7 and 28 days using different mix design methods (IS, ACI, and DOE). Results indicate that the 7-day compressive strength is similar for IS and ACI methods but lower for DOE. However, at 28 days, IS method outperforms ACI and DOE methods. Despite lower strength values, the DOE method required the least cement content. Visual representation and comparison with controlled concrete reveal a strength reduction in recycled aggregate concrete (RAC), attributed to 100% recycled aggregates, impacting hydration and strength development.

Keywords: Concrete, aggregates, compressive strength, workability, durability, permeability, recycled aggregates, sustainable construction.

INTRODUCTION

Concrete stands as the predominant construction material globally, witnessing an annual consumption estimated to range from 21 to 31 billion tonnes. It surpasses all other man-made materials in usage and is second only to food and water in terms of consumption by humanity. Approximately 7.5 billion cubic meters of concrete are manufactured annually, equating to more than one cubic meter for each individual on Earth. The production of concrete necessitates significant material resources, including cement, sand, and aggregates. Many of these materials are naturally occurring and, due to their extensive utilization, are facing depletion. River sand, a crucial component, is diminishing rapidly, and the available quantity is falling short of demand. To address this scarcity, the construction industry has turned to alternative materials such as manufactured crushed stone sand. Additionally, aggregates are depleting, necessitating the identification and exploration of alternative resources [1–5].

The scarcity of raw materials has prompted several nations to embrace recycling as a solution to meet their requirements. Utilizing demolished materials, a substantial portion of this demand can be fulfilled. However, before integrating such secondary materials into concrete production, their viability needs thorough evaluation. This study focuses on testing demolished materials as an alternative resource for concrete production, aiming

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to conserve natural resources, align with social and environmental objectives, and contribute to sustainable construction practices.

OBJECTIVES

The study aims to assess the impact of recycled aggregates on the compressive strength of medium workability concrete. Specific objectives include investigating the influence of varying proportions (0%, 50%, 60%, 100%) of recycled aggregates, particularly 10 mm sizes, on compressive strength. The research seeks to compare the performance of mix design methods (IS, ACI, DOE) for recycled aggregate concrete (60% 20 mm, 40% 10 mm Size) at 7 and 28 days. Visual representation and comparison with controlled concrete will be utilized to analyze compressive strength variations. The ultimate goal is to provide insights for the judicious use of recycled aggregates in concrete applications [7–17].

METHODOLOGY

To make efficient use of this resource, it is essential to study the mix design methodology. This involves evaluating the characteristics of recycled aggregates, understanding their grading, size, workability, and other criteria to achieve the desired strength. Existing reports suggest that conventional mix design methods can be used for proportioning various constituents of recycled aggregate concrete. However, due to the higher water absorption of recycled aggregate, several researchers have noted a change in water and cement demand. For instance, studies indicate an 8% higher requirement of free water for recycled aggregate concrete compared to conventional concrete. They also observed that an additional 5 to 8% cement is needed to maintain the same water-cement ratio and achieve the same strength as conventional concrete. Modifications to conventional methods have been suggested by these researchers, but further trials are required for the finalization of mix proportions [18–24].

Currently, there are no precise guidelines available for proportioning recycled aggregate concrete mixes on a rational basis. Therefore, the present work attempts to develop such guidelines. While compressive strength is a crucial parameter in concrete mix design, it is known that concrete in its fresh state must also meet diverse requirements such as mixability, stability, transportability, flowability, compact ability, and finish ability, collectively referred to as workability. Concretes failing to meet these criteria may result in lower compressive strength or durability issues. Given the higher water absorption of recycled aggregates compared to normal aggregates, evaluating this property is crucial. Various researchers have emphasized the need for higher water adjustment in recycled aggregates to produce concrete with adequate workability.

RESULTS AND DISCUSSION

In the current study, the concrete was designed for medium workability. Initial experimentation with recycled aggregates involved understanding their impact in concrete. Various replacement proportions of recycled aggregates (0%, 50%, 60%, and 100%) were tested using conventional mix design methods. Considering the impact of 10 mm recycled aggregates on compressive strength, the study also assessed the substitution by size. Specimen comprised 100% recycled aggregate, with 60% being of 20 mm size and 40% of 10 mm size. A total of 18 cubes were tested at 7 and 28 days with varying percentage replacements.

From the data presented in Table 1, it is evident that the 7-day compressive strength, as determined by the IS method and ACI method, is identical at 14.41 N/mm^2, surpassing the corresponding value obtained by the DOE method (11.87 N/mm^2). However, at 28 days, the compressive strength obtained by the IS method, with a cement content of 447 kg/m^3, is higher at 25.20 N/mm^2 compared to the ACI method (19.29 N/mm^2) at a cement content of 383 kg/m^3 and the DOE method (17.45 N/mm^2) at a cement content of 373 kg/m^3.

Additionally, it is noteworthy that the DOE method exhibited the lowest strength values at both 7 and 28 days among the three methods for Set 1, which involves 100% recycled aggregates. Despite this, the DOE method necessitated the least cement content, standing at 373 kg/m^3, considering the designed water-cement ratio.

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Table 1. Compressive strength analysis for recycled aggregate concrete (60% 20 mm and 40% 10 mm Size)

S.N.	Mix design	w/c ratio	Mix proportion	Compressive strength			
				At 7 days (N/mm²)		*At 28 days (N/mm²)*	
1.	IS	0.43	1:1.56:1.62	13.32	14.40	24.46	25.20
				15.53		26.68	
				14.42		24.41	
2.	ACI	0.48	1:1.6:1.9	13.79	14.41	20.02	19.29
				14.42		17.80	
				15.01		20.01	
3.	DOE	0.55	1:1.8:1.90	11.12	11.87	17.79	17.45
				12.23		15.58	
				12.24		18.90	

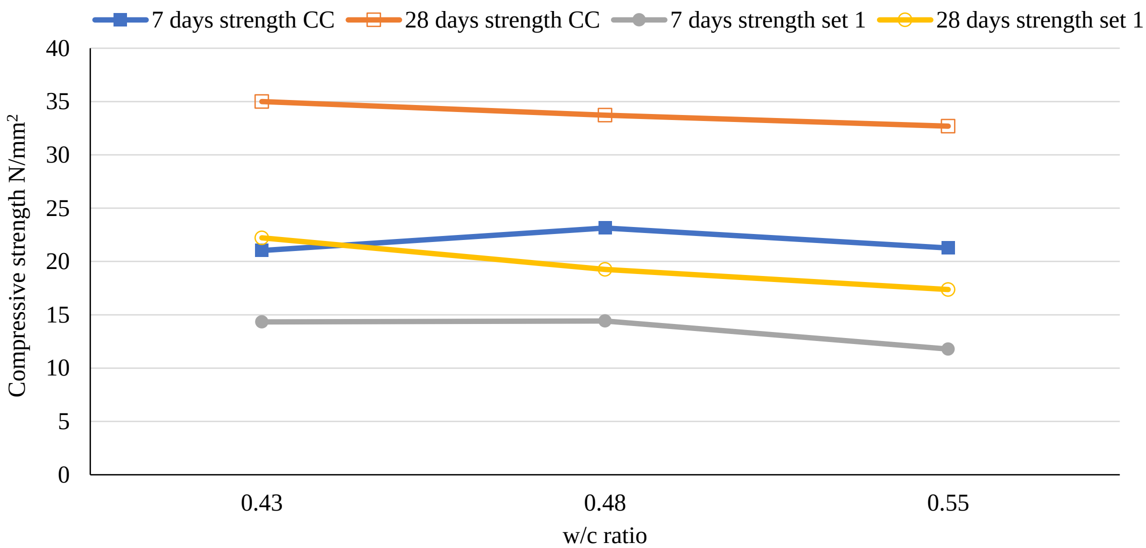

Figure 1. Comparative analysis of compressive strength for RAC against controlled concrete.

Figure 1 provides a visual representation of the comparison between Recycled aggregate concrete (60% 20 mm and 40% 10 mm Size) and controlled concrete. The graph illustrates the variations in compressive strength, determined by all three mix design methods, at 7- and 28-days using 100% recycled aggregates of sizes 10 mm and 20 mm for Recycled aggregate concrete (60% 20 mm and 40% 10 mm Size). The mix composition comprised 40% of 10 mm size recycled aggregates and 60% of 20 mm size.

Observing Figure 1 reveals that the 7-day compressive strength for Set 1 exhibits a nearly parallel trend to that of the controlled concrete. However, the controlled concrete consistently demonstrates higher strength values across all three mix design methods. Specifically, at 7 days, the strength values for the IS method, ACI method, and DOE method with controlled concrete are 21.03 N/mm^2 (water-cement ratio of 0.43), 23.10 N/mm^2 (water-cement ratio of 0.48), and 21.18 N/mm^2 (water-cement ratio of 0.55), respectively.

Similarly, at 28 days, both Set 1 and controlled concrete share a similar trend. A reduction in strength of 36%, 42%, and 46% is observed for controlled concrete at 28 days using the IS, ACI, and DOE methods, respectively. Notably, the reduction in compressive strength by the IS method is the least, attributed to its higher cement composition. The strength loss in RAC can be attributed to the use of 100% recycled aggregates in place of normal aggregates. Additionally, the strength decrease may be linked to the higher water absorption of the fine recycled aggregates, withdrawing the necessary amount

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of water required for the hydration of cement particles crucial for strength development. Consequently, the utilization of recycled aggregates, both 10 mm and 20 mm in proportions of 40% and 60%, respectively, has resulted in reduced strength at both 7 and 28 days compared to control concrete (CC).

CONCLUSION

The work underscores the trade-offs associated with using recycled aggregates in concrete. While the Department of Environment (DOE) method demands the least cement content, it exhibits the lowest compressive strength. The observed reduction in strength in recycled aggregate concrete (60% 20 mm and 40% 10 mm Size) at 7 and 28 days, compared to controlled concrete, can be linked to the exclusive use of recycled aggregates. The higher water absorption of fine recycled aggregates contributes to a decrease in strength due to insufficient water for cement hydration. The study highlights the need for a balanced approach in incorporating recycled aggregates to maintain acceptable strength characteristics in concrete applications.

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