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Experimental Investigation of Mechanical Properties of Basalt Fiber Reinforced Recycled Aggregate Concrete (BF-RAC)

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ABSTRACT

This study investigates the mechanical properties of Basalt Fiber (BF)-reinforced recycled aggregate concrete (RAC) in the context of the rapidly evolving construction industry, especially in developing countries. With a growing need for sustainable building materials globally, RCA is recognized as a viable alternative for natural aggregate. The research primarily focuses on analyzing the impact of BF with varying contents and an optimum length of 12mm on the mechanical properties of RAC at 28 days. The findings of this research emphasize the significance of BF content, identifying it as the main factor influencing concrete's mechanical properties within the tested fiber content range (0.15% to 0.25%). Notably, an optimal BF content of 0.2% is revealed, providing valuable insights for enhancing the sustainability and mechanical performance of concrete in the construction industry.

KEYWORDS: Recycled Aggregate, Basalt Fiber, sustainable material, mechanical properties

1 INTRODUCTION

Concrete, a widely used building material, exerts a substantial impact on natural resources and the environment[1]. The rapid growth of the construction industry has led to a surge in annual waste production, necessitating immediate attention for sustainable construction practices[2-4]. Efficient utilization of recycled materials is imperative to mitigate waste, and the development of recycled aggregate concrete (RAC) represents a crucial step toward green construction[5, 6]. However, RAC faces performance challenges compared to natural aggregate concrete due to adhered mortar, resulting in high porosity and water absorption[7, 8].

To enhance the performance of RAC, various modifications, such as the introduction of fibers, soaking reagents, nano materials, and fly ash, have been explored by researchers. These modifications have shown significant improvements in the mechanical and durability properties of RAC. This study specifically delves into the incorporation of basalt fibers in recycled aggregate concrete, aiming to contribute valuable insights into optimizing the mechanical performance of sustainable construction materials.

2 EXPERIMENTAL PROCEDURE

In this experimental investigation, we aim to assess the key mechanical properties. Three percentages of Basalt Fibers (0.15%,0.20%,0.25%) will be taken by the weight of binder. Coarse aggregates were entirely replaced with natural aggregates at a 100% replacement rate. Compressive, tensile and flexure tests were performed. An overview of the experimental program is presented in Table 1.

Table 1: Summary of tests performed to investigate mechanical properties

Testa performed	Specimens Tested	Dimensions (in)	IDs	No. of Specimens
Compression Test	Cylinders	6x12	CRA-BF0%	3
			CRA-BF0.15%	
			CRA-BF0.20%	
			CRA-BF0.25%	
Tensile Test	Cylinders	6x12	TRA-BF0%	3
			TRA-BF0.15%	
			TRA-BF0.20%	
			TRA-BF0.25%	
Bending test	Beams	4x6x18	BRA-BF0%	3
			TRA-BF0.15%	
			TRA-BF0.20%	
			TRA-BF0.25%	

2.1 Raw materials

In this study the RCA used is generated using raw materials sourced from the concrete laboratory at UET Taxila. The waste undergoes reception and processing, yielding various products, with aggregate being the primary outcome. The procedure encompasses crushing, metal separation via a magnet, manual elimination of additional impurities (such as plastic and wood), and the classification of aggregate was done by sieve analysis. The size range for the coarse aggregate spans from 2.36 mm to 20 mm. Ordinary Portland cement is utilized, and the fine aggregate consists of natural river sand with a fineness modulus of 2.67. A polycarboxylic high-performance water-reducing agent is employed, achieving a water reduction rate of 20%. Table 2 displays the physical properties of BF utilized in this investigation.

Table 2: Physical properties of BF

Density (kg/m3)	Single dimension diameter (μm)	Length (mm)	Tensile strength (MPa)	Elastic modulus (GPa)
2.65	7–15	12	3000–4800	91–110

2.2 Sample preparation

Prior to pouring the sample, the Recycled Concrete Aggregate (RCA) underwent a cleaning and air-drying process. During the mixing of Recycled Aggregate Concrete (RAC), RCA and sand were initially combined, stirred for 60 seconds; subsequently, cement and half of the required water were introduced, mixed for 30 seconds. Further, Blast Furnace slag (BF) was added in two increments, with each addition followed by 60 seconds of stirring. Finally, the remaining half of the water and a water-reducing agent were included, and the mixture was stirred for 180 seconds. Water and BF were added in two stages to achieve the necessary stirring state, as illustrated in Fig. 3 of the RAC preparation flow chart. After the casting and demoulding process, the samples underwent curing at room temperature. This study involved the pouring of 36 specimens to assess the 28-day mechanical properties of RAC.

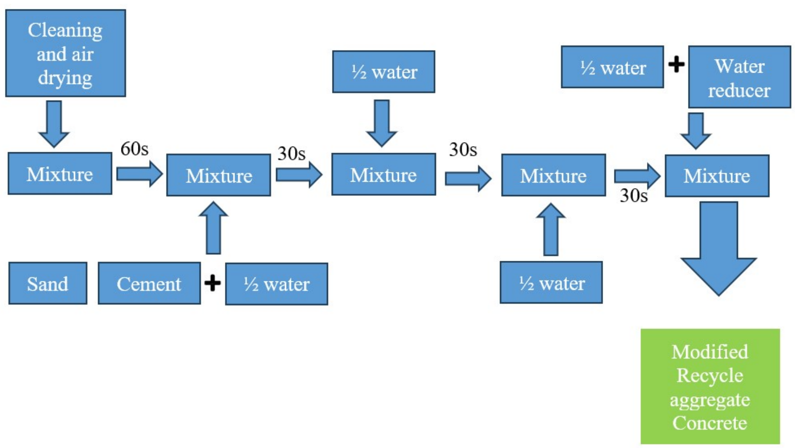

Figure 1: Schematic diagram of formation of Basalt fiber recycled courses aggregate concrete

3 RESEARCH METHODOLOGY

3.1 Compression testing

Compressive strength tests were conducted on twelve-cylinder specimens to investigate the compressive strength. One batch having ID CRA-BF0% were served as the control group. Compression testing machine (CTM) machine was used for testing and rate of loading was kept 50 psi/s as per ASTM C39.

3.2 Split Tensile testing

Tensile strength examinations were performed on twelve cylindrical samples to explore their tensile capabilities. The control group was represented by a batch with the ID TRA-BF0%. The Compression Testing Machine (CTM) was employed for testing, and the loading rate was maintained at 200 psi/s in accordance with ASTM C496.

3.3 Flexural strength Test

Twelve beam specimens were produced and underwent a 4-point bending test. Among the twelve specimens, three served as benchmark specimens (BRS-BF0%), while the remaining nine specimens featured various percentages of BF (BRS-BF0.15%, BRS-BF0.20%, BRS-BF0.25%).

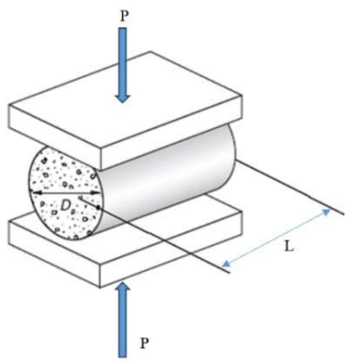

Figure 2: Schematic Diagram of Split tensile testing

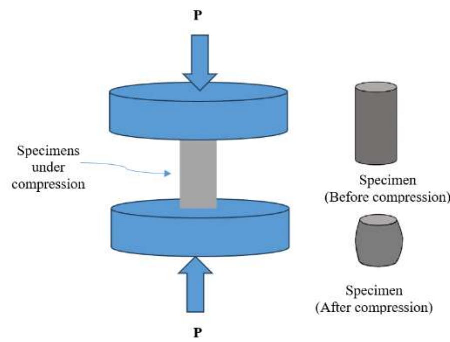

Figure 3: Schematic diagram of compression testing

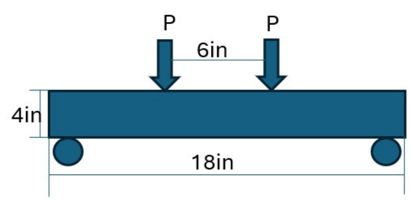

Figure 4: Schematic diagram of bending test

4 RESULTS AND ANALYSIS

4.1 Compressive Strength results

As outlined in Tables 5, the influence of BF content on RAC varies during the 28-day curing period, exhibiting an initial decline followed by an ascent. The compressive strength of RAC experiences fluctuations with increasing BF content. At 28 days with CRAC-BF0.20%, the compressive strength of concrete reaches its maximum, demonstrating regularity before subsequently declining. With a BF content of 0.15%, there is a reduced formation of effective "bearing networks" in the matrix, impacting the compactness of the concrete matrix and resulting in a slightly lower compressive strength of RAC. Conversely, at a BF content of 0.2%, there is an 11.20% increase in compressive strength.

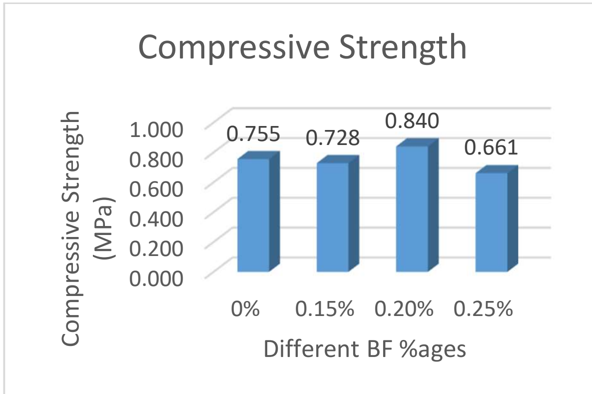

Figure 5: Compressive strength results at different percentages of BF(0.15%, 0.20%, 0.25%)

4.2 Split tensile Strength results

The assessment of concrete's mechanical properties often relies on the splitting tensile strength, a crucial indicator. In practical engineering scenarios, the preference is typically for the splitting tensile test over the axial tensile test. The 28-day splitting tensile strength of TRAC consistently rises with an increase in BF content, reaching 95% of the concrete's 28-day strength. The most noteworthy surge in tensile strength occurs, particularly at a BF content of 0.2%, where the strength growth rate peaks. This happens because the BF is evenly spread during mixing at this level, making the concrete bond better and, as a result, increasing its tensile strength.

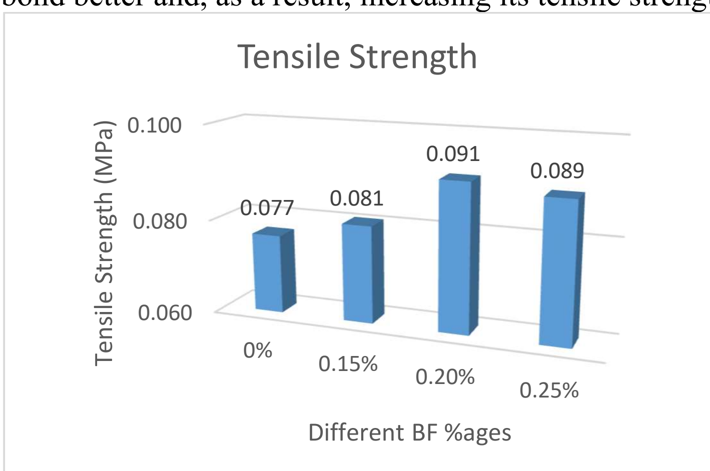

Figure 6: Split tensile strength results at different percentages of BF(0.15%, 0.20%, 0.25%)

4.3 Flexural Strength results

To evaluate the flexural performance, toughness, and deformation of concrete beams, the flexural test is a crucial measure. It provides insights into the flexural strength and failure of the concrete beams. Particularly, with a basalt fiber (BF) content of 0.15%, the increase in flexural strength of basalt fiber-reinforced recycled aggregate concrete (BF-RAC) at 28 days is relatively modest compared to a BF content of 0.20%. Incorporating an optimal amount of BF effectively utilizes the bridging effect of the fibers, complemented by the strong tensile strength of BF. This combination absorbs energy through deformation, breakage, and pullout. However, beyond a BF content of 0.20%, there is a rapid decline in bending toughness.

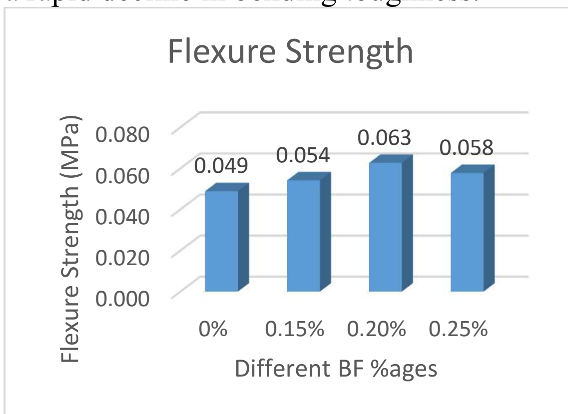

Figure 7: Flexural strength results at different percentages of BF(0.15%, 0.20%, 0.25%)

5 CONCLUSION

In conclusion, this study illuminates the nuanced impact of Basalt Fiber (BF) content on the mechanical characteristics of Basalt Fiber-Reinforced Recycled Aggregate Concrete (BF-RAC) in comparison to Recycled Aggregate Concrete (RAC). The optimal compressive strength is achieved at a BF content of 0.20%, with a decrease noted at 0.15% due to diminished "bearing networks." The splitting tensile strength of BF-RAC consistently rises, reaching 95% of the concrete's 28-day strength, particularly at 0.20% BF content, attributed to improved BF dispersion. Flexural tests emphasize the significance of the right BF content, where 0.15% exhibits a moderate increase compared to 0.20%, highlighting the bridging effect of fibers and the utilization of tensile strength. However, a notable decline in bending toughness becomes apparent beyond 0.20% BF content. These findings provide valuable insights for optimizing the mechanical performance of BF-RAC in practical engineering applications, contributing to advancements in sustainable and enhanced concrete materials.

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