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Study on the Fundamental Mechanical Properties of Fully Recycled Aggregate Concrete Reinforced with Basalt Fiber

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ABSTRACT: Fully recycled aggregate concrete (FRAC) exhibits reduced mechanical properties compared to conventional concrete due to the weakened interfacial transition zone (ITZ). To enhance the performance of FRAC, this study incorporates basalt fiber (BF) and investigates the effects of different fiber contents (0%–0.20%) and lengths (6mm–30mm) on the compressive and splitting tensile strength of FRAC. Experimental results demonstrate that an appropriate BF dosage can significantly improve the mechanical properties of FRAC. The optimal enhancement effect is achieved at a fiber content of 0.10% and a fiber length of 12mm–18mm, resulting in an 11.8% increase in compressive strength and a 16.4% increase in splitting tensile strength. The reinforcement mechanism is primarily attributed to the filling effect, bridging effect, and crack resistance effect, which enhance matrix density and restrict crack propagation. However, excessive fiber content or overly long fibers (>18mm) lead to fiber agglomeration, which adversely affects interfacial bonding and consequently reduces concrete strength. This study indicates that a rational incorporation of BF can optimize the mechanical properties of FRAC, providing a theoretical foundation for the design of high-performance recycled concrete.

KEYWORDS: Fully recycled aggregate concrete; Basalt fiber; Compressive strength; Splitting tensile strength; Reinforcement mechanism.

I. INTRODUCTION

With the rapid progress of urbanization, the construction industry has generated a massive amount of construction and demolition waste (CDW) [1-3]. Traditional disposal methods, including landfilling and low-efficiency recycling, not only occupy substantial land resources but also cause severe environmental pollution. Consequently, increasing the resource utilization rate of CDW, particularly for the production of recycled aggregate concrete (RAC), has become a key focus in the field of green construction and sustainable development [4-7].

Fully recycled aggregate concrete (FRAC) refers to concrete in which 100% of the natural coarse and fine aggregates are replaced with recycled aggregates [8-10]. Compared to conventional concrete, FRAC significantly reduces natural resource consumption and carbon emissions. However, due to the rough surface texture, high water absorption, and weakened interfacial transition zone (ITZ) of recycled aggregates, FRAC generally exhibits lower compressive and tensile strengths than natural aggregate concrete [11-13]. Therefore, optimizing its microstructure and improving its mechanical properties have become critical research priorities.

Basalt fiber (BF) is a high-performance inorganic fiber derived from the melting and drawing of natural basalt rock. It is characterized by high strength, high modulus, excellent thermal resistance, and superior chemical stability [14-16]. In recent years, BF has been widely applied in cement-based materials due to its outstanding reinforcement effects. Studies have shown that BF can enhance the ITZ of concrete through bridging and crack resistance effects, thereby improving the cracking resistance and mechanical performance of conventional concrete [17-20]. Thus, an appropriate addition of BF can effectively enhance the cracking resistance, impact resistance, and toughness of concrete, improving its overall mechanical properties.

However, research on the synergistic effects of BF and recycled aggregate remains limited, particularly regarding its reinforcement mechanisms and optimal dosage in FRAC systems. Therefore, this study aims to investigate the





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influence of BF on the mechanical properties of FRAC and reveal its reinforcement mechanisms, providing valuable insights for the widespread application of high-performance FRAC.

II. EXPERIMENTAL PROGRAM

2.1 Materials

Cement: The cement used in this study is PC 42.5 composite Portland cement, produced by Southern Cement Company in Yiyang, Hunan Province. The cement has a density of 3128 kg/m³.

Recycled Aggregate: The recycled aggregate was obtained by crushing and sieving discarded C15–C40 ordinary concrete specimens from laboratory waste.Recycled coarse aggregate (RCA): Particle size ranges from 5 mm to 20 mm, with a crushing value of 9.7 and an apparent density of 2552 kg/m³.Recycled fine aggregate (RFA): Particle size ranges from 0.075 mm to 4.75 mm, with a fineness modulus of 3.62 and an apparent density of 2350 kg/m³.Figure 1 presents the recycled aggregate samples.



Fig.1 (a) RCA

Fig.1 (b) RFA

Fig. 2 (d) 24mm

Basalt Fiber: The basalt fiber used in this study was supplied by Zhejiang Shijin Basalt Fiber Co., Ltd. It has an elastic modulus of 90 GPa, a diameter of 17 µm, and is available in lengths of 6 mm, 12 mm, 18 mm, 24 mm, and 30 mm. The fiber samples are shown in Figure 2.



Fig. 2 (a) 6mm

Fig. 2 (b) 12mm

Fig. 2 (c) 18mm

Fig. 2 (e) 30mm

Admixture: A high-performance liquid polycarboxylate superplasticizer was used, with a water-reducing rate of 35%.

2.2 Specimen design and mix proportions

The experiment consists of two groups: ordinary fully recycled aggregate concrete (FRAC) group and basalt fiberreinforced FRAC group, forming a comparative study. The basalt fiber volume fractions (0%, 0.05%, 0.1%, 0.15%, 0.2%) and fiber lengths (6 mm, 12 mm, 18 mm, 24 mm, 30 mm) are used as variables. The mix proportion design is presented in Table 1, and the specimens are shown in Figure 3.





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Fig. 3 Specimen Curing

Table.1 Experimental Mix Proportion Design

Combination	Water	Cement	RCA	RFA	Superplasticizer	BF Content	BF Length
	(Kg/m ³)	(%)	(mm)				
FRAC-0	170	567	655.5	655.5	8.5		
BF-FRAC-1	170	567	655.5	655.5	8.5	0.05	6
BF-FRAC-2	170	567	655.5	655.5	8.5	0.05	12
BF-FRAC-3	170	567	655.5	655.5	8.5	0.05	18
BF-FRAC-4	170	567	655.5	655.5	8.5	0.05	24
BF-FRAC-5	170	567	655.5	655.5	8.5	0.05	30
BF-FRAC-6	170	567	655.5	655.5	8.5	0.10	6
BF-FRAC-7	170	567	655.5	655.5	8.5	0.10	12
BF-FRAC-8	170	567	655.5	655.5	8.5	0.10	18
BF-FRAC-9	170	567	655.5	655.5	8.5	0.10	24
BF-FRAC-10	170	567	655.5	655.5	8.5	0.10	30
BF-FRAC-11	170	567	655.5	655.5	8.5	0.15	6
BF-FRAC-12	170	567	655.5	655.5	8.5	0.15	12
BF-FRAC-13	170	567	655.5	655.5	8.5	0.15	18
BF-FRAC-14	170	567	655.5	655.5	8.5	0.15	24
BF-FRAC-15	170	567	655.5	655.5	8.5	0.15	30
BF-FRAC-16	170	567	655.5	655.5	8.5	0.20	6
BF-FRAC-17	170	567	655.5	655.5	8.5	0.20	12
BF-FRAC-18	170	567	655.5	655.5	8.5	0.20	18
BF-FRAC-19	170	567	655.5	655.5	8.5	0.20	24
BF-FRAC-20	170	567	655.5	655.5	8.5	0.20	30

III. COMPRESSIVE STRENGTH OF BFFRAC

3.1 Experimental method

In this study, 150 mm \times 150 mm \times 150 mm cubic specimens were used for compressive strength testing. The mix proportions of the specimens are detailed in Table 1. The basalt fiber content was set at 0%, 0.05%, 0.10%, 0.15%, and 0.20%, while the fiber lengths were 6 mm, 12 mm, 18 mm, 24 mm, and 30 mm, resulting in a total of 21 experimental groups. Each group contained three specimens, making a total of 63 specimens. The experiment was conducted according to the Chinese national standard GB/T 50081-2019 "Standard Test Method for Mechanical Properties of

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Ordinary Concrete" [21]. A 3000 kN hydraulic testing machine was used for loading, with a loading rate of 0.5 MPa/s, continuing until the specimen failed. The maximum load was recorded for each test.All specimens were cured for 28 days before testing. The effect of different fiber contents and fiber lengths on the compressive strength of FRAC was analyzed through comparative studies. The loading process and specimen failure patterns are illustrated in Figure 4.



Fig. 4 (a) Compressive Strength Test Loading



Fig. 4 (b) Failure of Compressive Strength Specimen

3.2 Experimental results

As shown in Figure 5, the incorporation of basalt fiber significantly enhances the compressive strength of fully recycled aggregate concrete (FRAC), with varying effects depending on the fiber content. The compressive strength peaks at a fiber content of 0.10%, with the L=12 mm specimen exhibiting the highest improvement of 11.8% compared to the fiber-free specimen, reaching a maximum compressive strength of 63.49 MPa. This enhancement is primarily attributed to the fiber filling effect, which helps mitigate internal microcracks, increasing the matrix density, while the bridging effect further restricts crack propagation. However, when the fiber content exceeds 0.15%, the compressive strength begins to decline. Notably, in the L=18 mm group, the strength reduction is most pronounced, decreasing by 3.9%. This decrease is likely due to fiber agglomeration, which disrupts the uniformity of the concrete mixture. Therefore, an optimal fiber content of approximately 0.10% is recommended for effectively enhancing the compressive performance of FRAC.

As illustrated in Figure 6, the compressive strength increases with fiber length from 6 mm to 12 mm and 18 mm. Specifically, at 0.10% fiber content, the L=12 mm group demonstrates a 7.8% higher compressive strength than the L=6 mm group, indicating that appropriately sized fibers can be evenly distributed within the concrete matrix, fully utilizing the bridging effect to enhance load-bearing capacity. However, when the fiber length increases beyond 18 mm to 24 mm and 30 mm, the compressive strength starts to decline. The L=30 mm group exhibits a 2.9% lower compressive strength than the L=12 mm group, which may be attributed to excessive fiber entanglement, leading to reduced workability and weakened bonding within the ITZ. This suggests that the optimal fiber length for enhancing FRAC compressive performance is between 12 mm and 18 mm.





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4.1 Experimental method

The splitting tensile strength test was conducted using 150 mm \times 150 mm \times 150 mm cubic specimens. The mix proportions for basalt fiber-reinforced fully recycled aggregate concrete (FRAC) are detailed in Table 1. The fiber content was set at 0%, 0.05%, 0.10%, 0.15%, and 0.20%, while the fiber lengths were 6 mm, 12 mm, 18 mm, 24 mm, and 30 mm. A total of 21 experimental groups were tested, with three specimens per group, resulting in 63 specimens. These specimens were used to analyze the effect of different fiber contents and lengths on the splitting tensile strength of FRAC. The experiment was conducted in accordance with GB/T 50081-2019 "Standard Test Method for Mechanical Properties of Ordinary Concrete" [21]. A hydraulic testing machine was used for loading, with a loading rate of 0.05 MPa/s, continuing until the specimen failed. The maximum load at failure was recorded. All specimens were cured for 28 days before testing. Comparative analysis was performed to assess the influence of fiber content and length on splitting tensile strength, aiming to explore the reinforcement mechanisms and optimize the mix proportions. The loading process and failure modes of the specimens are illustrated in Figure 7.





Fig. 7 (a) Splitting Tensile Strength Test Loading Fig. 7 (b) Failure of Splitting Tensile Strength Specimen





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4.2 Experimental results

As shown in Figure 8, the incorporation of basalt fiber improves the splitting tensile strength of fully recycled aggregate concrete (FRAC), but the enhancement effect varies significantly depending on the fiber content. The FRAC-0 group, which contains no fibers, exhibits a splitting tensile strength of approximately 3.97 MPa. As the fiber content increases, the splitting tensile strength gradually improves, reaching a peak at 0.10% fiber content, with the L=12 mm group achieving a maximum strength of 4.62 MPa, representing a 16.4% increase compared to the fiber-free specimen. This result indicates that an appropriate fiber dosage can effectively enhance the toughness and tensile load-bearing capacity of FRAC.

However, when the fiber content exceeds 0.15%, the splitting tensile strength begins to decline, with the L=18 mm group experiencing the most significant drop (4.8% decrease). This phenomenon may be attributed to the fiber agglomeration effect, which leads to localized stress concentration within FRAC, thereby reducing its overall tensile strength. Additionally, excessive fiber content may negatively impact the bonding performance between the cement matrix and aggregates, weakening the ITZ. Consequently, an optimal fiber content of 0.10% is recommended, as it effectively enhances the splitting tensile performance of FRAC, while exceeding this dosage may reduce the reinforcement effect.

As illustrated in Figure 9, fiber length also has a significant influence on the splitting tensile strength of FRAC. With increasing fiber length, the splitting tensile strength reaches its peak between 12 mm and 18 mm. Specifically, at 0.10% fiber content, the L=18 mm group exhibits a 10.3% higher tensile strength than the L=6 mm group. This suggests that fibers of appropriate length can effectively bridge cracks and improve the tensile performance of FRAC.

However, when the fiber length further increases to 24 mm and 30 mm, the splitting tensile strength declines, with the L=30 mm group showing a 4.7% reduction compared to the L=18 mm group. This reduction is likely due to poor fiber dispersion in the concrete mixture, as longer fibers tend to form agglomerates during mixing, preventing uniform distribution. Moreover, the reinforcement effect of fibers becomes saturated beyond a certain length, and excessively long fibers may disrupt the integrity of the cement matrix. Therefore, the optimal fiber length is between 12 mm and 18 mm, which effectively improves the splitting tensile strength of FRAC, whereas fibers longer than 18 mm may lead to a diminished reinforcement effect.



Splitting Tensile Strength of FRAC

Fig. 9 Effect of BF Length on the Splitting Tensile Strength of FRAC

V. CONCLUSION

1. The incorporation of an appropriate amount of basalt fiber can effectively enhance the compressive strength and splitting tensile strength of fully recycled aggregate concrete (FRAC). Compared to fiber-free specimens, at a fiber content of 0.10%, the compressive strength increased by up to 11.8%, while the splitting tensile strength improved by 16.4%. However, when the fiber content exceeds 0.15% or the fiber length surpasses 18 mm, the strength of FRAC





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decreases. This reduction is likely due to fiber agglomeration and deterioration of the ITZ. Therefore, the reinforcement effect of basalt fiber is dependent on proper dosage and length control.

2. The optimal mechanical performance of FRAC is achieved when the fiber content is 0.10%, and the fiber length ranges between 12 mm and 18 mm. Within this range, fibers are evenly distributed in the concrete matrix, enhancing its density while also bridging and resisting cracks. Under these conditions, both compressive and tensile strength reach their maximum potential. However, exceeding this dosage or length may result in fiber entanglement, agglomeration, or weakened interfacial bonding, ultimately reducing the reinforcing effect.

3. The reinforcement mechanism of basalt fiber is primarily attributed to the filling effect, bridging effect, and crack resistance effect. The fibers fill internal microcracks, increasing matrix density, while also bridging cracks during loading, providing additional tensile resistance, delaying crack propagation, and improving the load-bearing capacity of the concrete. However, excessive fiber content or overly long fibers can lead to fiber agglomeration, which reduces the reinforcement effect and may cause stress concentration within FRAC, thereby weakening the ITZ strength. Therefore, in practical engineering applications, fiber content and length should be carefully controlled to maximize the reinforcing effect of basalt fiber, while avoiding the performance degradation associated with excessive fiber incorporation.

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REFERENCES

- [1] Nan L, Ruru H, Xiaohui L. Bibliometric analysis of research trends on solid waste reuse and recycling during 1992–2016[J]. Resources, Conservation and Recycling, 2018, 130: 109-117.
- [2] Thomas C, Setien J, Polanco J A, et al. Durability of recycled aggregate concrete [J]. Construction and Building Materials, 2013, 40: 1054-1065.
- [3] Zhang H, Xiao J, Tang Y, et al. Long-term shrinkage and mechanical properties of fully recycled aggregate concrete: Testing and modelling[J]. Cement and Concrete Composites, 2022, 130: 104527.
- [4] Duan Z, Poon C S, Xiao J. Using artificial neural networks to assess the applicability of recycled aggregate classification by different specifications[J]. Materials and Structures, 2017, 50: 1-14.
- [5] Dong L, Fu Y, He M, et al. Recycling coarse aggregates from concrete using high voltage pulses[J]. Construction and Building Materials, 2025, 458: 139669.
- [6] Wu E, Ma X, Fang C, et al. Strength performance and microscopic mechanism of cement mortar incorporating fine recycled concrete aggregate and natural sand[J]. Journal of Building Engineering, 2025: 111767.
- [7] Bao J, Li S, Zhang P, et al. Influence of the incorporation of recycled coarse aggregate on water absorption and chloride penetration into concrete[J]. Construction and Building Materials, 2020, 239: 117845.
- [8] Wang J, Che Z, Zhang K, et al. Performance of recycled aggregate concrete with supplementary cementitious materials (fly ash, GBFS, silica fume, and metakaolin): Mechanical properties, pore structure, and water absorption[J]. Construction and Building Materials, 2023, 368: 130455.
- [9] Le T, Le Saout G, Garcia-Diaz E, et al. Hardened behavior of mortar based on recycled aggregate: Influence of saturation state at macro-and microscopic scales[J]. Construction and Building Materials, 2017, 141: 479-490.
- [10] Zhao Y, Zeng W, Zhang H. Properties of recycled aggregate concrete with different water control methods[J]. Construction and Building Materials, 2017, 152: 539-546.
- [11] Mefteh H, Kebaïli O, Oucief H, et al. Influence of moisture conditioning of recycled aggregates on the properties of fresh and hardened concrete[J]. Journal of cleaner production, 2013, 54: 282-288.
- [12] Brand A S, Roesler J. Interfacial transition zone of cement composites with recycled concrete aggregate of different moisture states[J]. Advances in Civil Engineering Materials, 2018, 7(1): 87-102.
- [13] Guerzou T, Mebrouki A, Castro-Gomes J. Study of concretes properties based on pre-saturated recycled aggregates[J]. Journal of Materials and Engineering Structures, 2018, 5(3): 279-288.
- [14] Xinzhong W, Chuanxi L. Experimental study on the axial compression of short basalt fiber reinforced concrete columns with spiral stirrups[J]. Journal of Engineering Science and Technology Review, 2017, 10(1): 55-60.





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- [15] Xianggang Z, Gaoqiang Z, Ping X, et al. Mechanical properties under compression and microscopy analysis of basalt fiber reinforced recycled aggregate concrete[J]. Materials, 2023, 16(6): 2520.
- [16] Chujie J, Xiucheng Z, Weizhi C, et al. Mechanical property and dimensional stability of chopped basalt fiberreinforced recycled concrete and modeling with fuzzy inference system[J]. Buildings, 2022, 13(1): 97.
- [17] Li Y, Wang Q, Xu S, et al. Study of eco-friendly fabricated hydrophobic concrete containing basalt fiber with good durability[J]. Journal of Building Engineering, 2023, 65: 105759.
- [18] Chen Z, Yu J, Nong Y, et al. Beyond time: Enhancing corrosion resistance of geopolymer concrete and BFRP bars in seawater[J]. Composite Structures, 2023, 322: 117439.
- [19] Li Y, Zhang J, He Y, et al. A review on durability of basalt fiber reinforced concrete[J]. Composites Science and Technology, 2022, 225: 109519.
- [20] Kizilkanat A B, Kabay N, Akyüncü V, et al. Mechanical properties and fracture behavior of basalt and glass fiber reinforced concrete: An experimental study[J]. Construction and Building Materials, 2015, 100: 218-224.
- [21] GB/T 50081-2019, Standard for Physical and Mechanical Performance Testing Methods of Concrete [S]. (in Chinese)









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