



Assessing the Influence of Basalt Fiber on the Workability of 100% Recycled Aggregate Concrete

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Abstract. To investigate the impact of basalt fiber on the workability of recycled aggregate concrete, various lengths of basalt fibers were incorporated at 0.1, 0.2, and 0.3% volume content. This was done with a 100% replacement of recycled coarse aggregate to produce basalt fiber recycled aggregate concrete. Through workability assessment of the recycled concrete mixture, the effect of different lengths and quantities of basalt fibers on the operational effectiveness of recycled concrete was analyzed. Findings indicated that the inclusion of basalt fibers resulted in a reduction in the slump. Specifically, the slump of recycled aggregate concrete containing a single fiber decreased as both the length and content of the fiber increased, consequently reducing its workability. Conversely, the slump of 100% recycled aggregate concrete with mixed fibers demonstrated a pattern of initially increasing and then decreasing with the rise in fiber content.

Keywords: recycled aggregate concrete; basalt fiber; workability; slump test

1 Introduction

The addition of basalt fiber (BF) to recycled aggregate concrete (RAC) has become quite attractive in recent years due to its capacity to enhance the mechanical properties and sustainability. The basalt fibers are made from volcanic rocks, with high tensile strength and chemical resistance, whereas they are friendly to the environment. The use of recycled aggregates in concrete is crucial to sustainable construction but usually faces setbacks such as a reduction in workability, a higher need for water, and a decline in mechanical performance. Over the years, researchers have come up with different ways of curbing such challenges, and among them has been the incorporation of basalt fiber. Basalt fibers have been seen to improve mechanical performance and durability, especially with some of the drawbacks posed by recycled aggregates. The high thermal stability and corrosion resistance of basalt fiber mainly depend on its chemical composition as silica and alumina, which would contribute to such attributes as better toughness and tensile strength in concrete. Research on the effect of basalt fibers on the workability of RAC shows some conflicting results. The other studies have concluded that basalt fiber enhances workability by reducing the segregation and bleeding of concrete,

while others say it reduces workability because of an increased tendency of friction between fibers and aggregates.

The introduction of basalt fibers in RAC has widely been reported to improve the mechanical properties. Basalt fibers considerably improve the compressive and tensile strengths and flexural strengths of concrete. For example, [1, 2] showed an improvement in the compressive strength and modulus of elasticity of RAC with the inclusion of basalt fibers. Mainly, the contribution of fiber addition increases total structural performance by bridging micro-cracks and delaying other failures of crack propagation. Besides compressive strength, tensile strength also improves for RAC with the inclusion of basalt fibers. Studies report that the fibers increase the tensile capacity by acting as additional reinforcement, which is an advantage in inhibiting crack formation under tensile loading [3]. Basalt fibers have also shown a favorable effect on flexural strength, which is an important parameter for structural design. Biradar et al. [4] reported that the flexural strength of RAC with basalt fibers is markedly high compared to conventional concrete. Similar research by High et al. [5] showed that basalt fibers entail enhanced fracture behavior on RAC. They highlighted the fact that basalt fiber-reinforced concrete showed higher toughness and better energy absorption capacity—properties quite important for resisting dynamic and impact loads. These properties help a lot in the applications where RAC is suffering from harsh loading conditions; therefore, the lifetime and endurance of the concrete structures are improved. It was further examined by Zhang et al. [6] regarding the microstructural changes of the RAC with basalt fiber addition, pointing to the ITZ between the fibers and the cement matrix. The enhanced ITZ leads to better load transfer and, at the same time, reduced porosity in the matrix—both key factors that relate to the mechanical properties and durability of the concrete.

Furthermore, high-performance concrete research work with basalt fiber reinforcement by Ayub et al. [7] exposed that the fibers contributed not only to increased strength characteristics but to greater durability of concrete under all types of environmental conditions as well. Their results further suggested that these basalt fibers helped in reducing shrinkage and cracking problems in RAC, hence potentially earning positive effects on service life. Basalt fibers have many benefits in using them with recycled aggregate concrete: for instance, it would have positive effects on the mechanical properties, durability, workability, and environmental friendliness. Basalt fibers were proven to enhance compressive, tensile, flexural strengths of RAC considerably, which would enhance structural integrity and performance under varied loading conditions. Moreover, other superior durability features, such as freeze-thaw cycles, chloride penetration, and high temperatures, resistance, will further improve the life expectancy and serviceability of RAC structures.

Besides these, inclusion of basalt fiber in recycled aggregate concrete also proves to be beneficial from an environmental and economic perspective. The fact that recycled aggregates allow building concrete is a rational practice in terms of conserving natural resources and reducing waste to the least. The sustainability of concrete production is also enhanced when this is used in combination with basalt fibers. They are thus more sustainable compared to synthetic fibers. The impact of basalt fiber production on the environment is also lower compared to other fiber types, such as carbon or glass fibers.

Therefore, the use of basalt fibers in RAC can have a positive contribution toward reducing the carbon footprint for concrete construction and offers substantial benefits from environmental and economic points of view. This presents immense benefits to a composite material of modern construction practices both from its sustainable nature and cost savings, using recycled aggregates coupled with reduced maintenance expenses. Economically, if basalt fibers are introduced into RAC, then it leads to cost saving over the lifecycle of the concrete structure. The improved durability and mechanical properties of RAC reinforced with basalt fibers reduce the frequency of repairs and maintenance, thus lowering long-term costs. Also, using basalt fiber improves the cost-effectiveness of the concrete, considering that recycled aggregates are normally cheaper than natural ones. Militký et al. [8] noted that, in comparison with other HPFs, the price of basalt fibers is quite competitive; thus, using them is economically viable to enhance RAC. Basalt fiber-reinforced RAC improves the cost-effectiveness and enhances performance, hence offering attractiveness to the public and private construction sector. Fiore et al. [9] carried out a broad review on the fiber of basalt and its composites while concentrating on the inherent properties of the fiber for enhancing the mechanical properties of concrete. This offers great advantages in the way these properties come to the rescue when concrete is exposed to very aggressive environmental conditions involving high temperatures and chemicals.

Several studies have been carried out on the influences of BF on RAC, but the results were mixed in relation to the workability of basalt fiber-reinforced RAC, which generally refers to ease of mixing, placing, and finishing. For example, a lot of research including that by [10] showed that the addition of basalt fibers deteriorates the workability of concrete. This is often explained by the higher friction of the fibers with the aggregates, which may hinder flowability of the concrete mix. This also leads to frictional effects that necessitate altering the water to cement ratio, or superplasticizer be administered to maintain the desired workability. In contrast, the test results for several other studies indicated that the use of basalt fibers enhanced the cohesiveness of RAC. Kizilkanat et al. [11] observed that, when basalt fibers were added in the mix, it restrains segregation as well as the bleeding consequently a more homogeneous and stable mix. This tendency of cohesion improvement may be particularly useful in preventing coarse aggregate separation and weak zone creation in concrete. Further studies by Chen et al. [12] have indicated that the size and aspect ratio of BF play a significant role in workability. It is thus that the findings prove that short fibers with a low aspect ratio have a lesser negative impact on workability. Utilize this information while making decisions regarding fiber types and sizes for striking the balance between mechanical advantage of basalt fibers and adequate workability. Ashteyat et al. [13] proceeded to conduct further investigate on the properties of basalt fiber-reinforced self-compacting concrete, suggesting that although workability could be corrected using appropriate admixtures and optimization of the mix design, many results would very much depend on the exact composition of the mixture. Suggestions from the research show an improvement in keeping the flowability and ease of placement of the concrete in good condition with the addition of superplasticizers, without seeing the benefits of basalt fibers at the expense of workability. Recently, [14] explored the combined effects of basalt fibers and nano-silica on the workability and mechanical properties of RAC. The authors showed

that a combination of these materials can bring an improvement in workability without significantly affecting strength.

The addition of nanosilica fills voids and reduces friction between aggregates and fibers, making the mix generally more cohesive and flowable. Li et al. [15] optimized the mixture ratio of BFRAC with Response Surface Methodology (RSM). The most important information coming from this research is obtained regarding the best proportion between basalt fiber, recycled aggregates, and other mix components to obtain optimal workability and mechanical performance. Balance of beneficial aspects and practical requirements for workability of the mix are possible with the design of the mix.

This paper investigates the effects of varying lengths and volume fractions of basalt fiber, in combination with 100% recycled coarse aggregate (RCA), on the workability performance of RAC. The objective is to determine the optimal mixture parameters that enhance the performance characteristics of RAC, making it a viable option for sustainable construction practices. The research will explore how different fiber lengths and volume fractions impact the ease of mixing, placing, and finishing, thereby addressing workability concerns that are critical in real-world applications. The findings from this phase will guide the selection of the most appropriate BF mix for further comprehensive study including mechanical, fracture, and durability properties.

2 Materials

2.1 Recycled Coarse Aggregate

The original concrete used to produce recycled coarse aggregate (RCA) in this test was obtained from discarded pavement concrete materials. The components were broken into appropriate sizes and then crushed by a small jaw crusher. The crushed aggregate is processed with a 4.75mm aperture. A gravel sieve was used to collect the sieved aggregates with a particle size between 5 and 20 mm obtaining the recycled coarse aggregate used in this test. The performance indicators of recycled coarse aggregate are shown in Table 1.

Table 1. Recycled coarse aggregate performance indicators

Apparent density(kg/m ³)	Bulk density (kg/m ³)	Crush value (%)	Water absorption (%)	Mud content (%)
2633	1450	20.5	4.97	0.4

To reduce the influence of high-water absorption of recycled coarse aggregate on the performance of recycled concrete, the recycled coarse aggregate was pretreated by the secondary modification method of nano-silicon dioxide cement paste before the test. The specific method started with soaking the recycled coarse aggregate in a 1% nano-silicon dioxide solution for 24 hours, dry it, and then soak it in a silicate cement paste with a water-cement ratio of 1:1 for 4 hours. During this period, it needs to be stirred well every 20 minutes. After that, the RCA was air-dried and ready for the experiment. The treated recycled coarse aggregate is shown in Figure 1.



Fig. 1. RCA after pre-treatment process

2.2 Basalt Fiber (BF)

The single fiber diameter is 7~15 μm , and the length is 6, 12, and 24mm respectively. The relevant physical and mechanical indicators are shown in Table 2 and the actual short-cut basalt fiber is shown in Figure 2.



Fig. 2. Basalt fiber

Table 2. Mechanical property of basalt fiber

Density (kg/m^3)	Elastic Modulus (GPa)	Tensile strength (GPa)	Extensibility (%)
2.65	95	3	2

2.3 Supplementary Materials

The water used in this test was ordinary tap water from the laboratory, the natural fine aggregate was natural medium sand, and the water reducer was polycarboxylic acid high-performance water reducer with a water reduction rate greater than 45% and a dosage of 1% of the cement dosage.

3 Experimental Setup

3.1 Mix Design

In order to explore the influence of basalt fiber length and its dosage on the working performance of recycled concrete, this paper considered basalt fiber length and volume dosage as control parameters when the replacement rate of recycled coarse aggregate is 100%. Among them, the BF lengths were divided to 4 cases: 6mm, 12mm, 24mm and mixed group (The mass ratio of the three length fibers is 1:1:1), and the BF volume dosages were designed into 3 cases: 0.1%, 0.2% and 0.3%. Based on the changes of the above influencing factors, including the group without fiber addition as the control group, a total of 13 working conditions of concrete mix design were carried out.

3.2 Test Method

Since basalt fiber has a low density and is easy to clump during mixing, this experiment used cement paste wrapping method to ensure the uniformity of concrete mixture. The mixing processes were the following. Firstly, half of the cement and water weighed according to the mix ratio were taken, basalt fiber was added and mixed for 1 minute. Secondly, recycled coarse aggregate, sand, remaining cement and water were put into the mixer and poured into the pre-mixed fiber cement slurry mixture, mixed up for 2 minutes. The slump of the mixture formed by the above process was measured in time according to the standard method.

4 Results and Discussion

Slump directly reflects the fluidity of concrete and is one of the important indicators of concrete working performance. The trend of slump with basalt fiber length and dosage is shown in Figure 3.

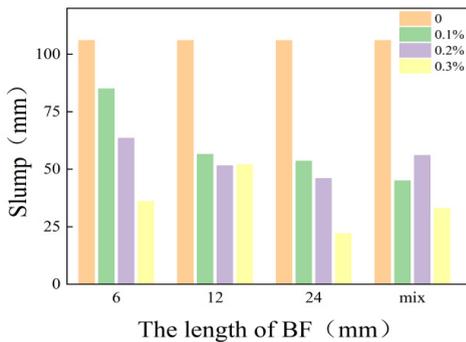


Fig. 3. Effects of basalt fiber on the slump of RAC

It can be seen from Figure 3 that compared with recycled concrete without fiber addition, the addition of basalt fiber leads to a decrease in the slump of recycled concrete. When the fiber length is 24 mm and the dosage is 0.3%, the slump decreased by 79.2%. Moreover, the slump of RAC with single fiber addition showed a decreasing trend with the increase of fiber length and dosage. The main reason for the decrease in slump after adding fiber is that basalt fiber has a small diameter and a large specific surface area, and needs to be wrapped with more cement slurry, which reduces the fluidity of concrete eventually. Meanwhile, the fibers dispersed in the concrete arrange a nearly uniform random mesh support structure inside the concrete mixture, which also inhibits the flow of concrete.

Applying the same amount of fiber dosage, the slump of RAC with single fiber addition generally showed a decreasing trend with the increase of fiber length. When the fiber dosage was 0.1%, the slump of the fiber length was 12 mm, which is 33.5% lower than that of 6 mm, and the slump of the fiber length is 24 mm, which is 37% lower than that of 6 mm (I don't understand this sentence, please check it again). When the fiber content is 0.3%, the slump of RAC increased first then decreased with the increasing of fiber length. This is because when the fiber length increases, the specific surface area of the fiber also increases. Longer fibers gathered and adhered to a large amount of cement slurry, resulting in reduction of concrete fluidity. Moreover, long fibers are easy to agglomerate and unevenly distributed making many gaps and pores between them and sequentially reducing fluidity of concrete.

When the fiber length was the same, the slump of single fiber recycled concrete showed a downward trend with the increase of fiber content. When the fiber length was 6 mm, the slump of the 0.2% fiber content decreased by 25.3% compared with 0.1%, and the slump of 0.3% decreased by 57.6% compared with 0.1%. This is because as the fiber content increases, the random mesh support structure inside the concrete mixture occupies more space. Since basalt fiber has a strong bonding force with cement-based materials, the cohesiveness of the mixture increases and the slump decreases.

The slump of mixed fiber in RAC increased first and then decreased with the increasing of fiber content. At 0.1% basalt fiber content, the slump was lower than that of single fiber RAC. According to fiber contents 0.2 and 0.3% respectively, the slumps of mixed fiber RAC were higher than that of single fiber RAC considering the same amount of contents (Fiber length was 24 mm). With an increase in mixed fiber content, the fibers in the mixtures become more uniformly and orderly distributed. This uniformity reduces gaps and pores, minimizes the space taken up by the random mesh support structure, enhances the mixture's fluidity, and consequently increases the slump.

5 Conclusions

1) The incorporation of basalt fiber results in a decreased slump of RAC. This is attributed to the large specific surface area of basalt fiber, which necessitates more cement slurry for encapsulation. Additionally, the fibers form a network within the concrete mixture, collectively slowing down the flow of RAC.

2) The slump of RAC mixed solely with fiber diminishes as both the length and dosage of basalt fiber increase. Consequently, the working performance of recycled aggregate concrete also declines, indicating that the performance of basalt fiber-reinforced RAC is influenced not only fiber length but dosage as well.

3) When the basalt fiber content in mixed fiber RAC surpasses 0.2%, the slump of the mixture exceeds that of single fiber ones (with a fiber length of 24mm) at the same content. This suggests that basalt fibers of various lengths possess equivalent quality. However, blending fibers does not significantly enhance the working performance of concrete. Future research should explore the impact of different mass ratios of basalt fibers on the performance of recycled aggregate concrete.

Acknowledgement

The authors greatly acknowledge resources support from Rajamangala University of Technology Thunyaburi, Thailand and Suihua University, China.

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