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EFFECT OF BASALT FIBER ASPECT RATIO ON MECHANICAL AND WORKABILITY PROPERTIES OF SELF-COMPACTING CONCRETE

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Highlights

- Basalt fiber improved flexural and splitting tensile strength of Self- Compacting Concrete
- Aspect ratio is an important parameter that effects the mechanical performance of fiber reinforced concrete.
- Increasing aspect ratio increases the mechanical and workability performance of fiber reinforced SCC.

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ABSTRACT: Self-compacting concrete (SCC) has become widely used thanks to its various advantages. SCC is also fiber reinforced, similar to conventional concrete. However, studies on SCC with fiber addition are limited. In this study, the effect of basalt fibers at different aspect ratios on the mechanical and workability properties of SCC was examined. Slump flow, V-funnel, compressive, flexural and splitting tensile strength tests were carried out within this study. Results showed that, although increasing the aspect ratio causes improvement in the workability properties of concrete, workability decreases compared to the reference SCC. Increases were observed in flexural and splitting tensile strengths with increasing aspect ratio. The compressive strength of the specimens that contains BF decreased compared to the reference sample because of the agglomeration effect. The results obtained were examined and discussed in detail.

Keywords: *Aspect ratio, Basalt, Fiber, Self compacting concrete*

1. INTRODUCTION

Concrete is the most significant and used building material, with its advantages such as high durability and strength, low cost, strong bond with reinforcement steel and plasticity [1], [2]. Besides these advantages, studies have shown a trend towards self-compacting concrete (SCC) to improve the workability of conventional concrete. SCC settles into concrete molds with its own weight and viscosity, without requiring any vibration or placement process. It is especially suitable for pouring concrete in places where vibration is difficult and at night. Low labor costs and less energy used for compaction are also advantages over conventional concrete [3]. SCC is produced similar to conventional concrete and is produced with a mixture of aggregates, binders, water, mineral, chemical additives and natural additives [4]–[6]. Although concrete is the most used building material with a good performance in terms of compressive strength, its tensile strength and brittleness are problems that need to be solved.

Researchers found that adding fiber to concrete mixtures improved the mechanical performance (Flexural and tensile strength, crack resistance, ductility, toughness) of concrete [7]. Basalt, steel, carbon, glass, polypropylene and natural fibers are mostly studied fiber types in the literature [8], [9]. Basalt fiber (BF) is produced from basalt rock with molting in high temperature. BF has high tensile strength, fire and impact resistance. Compared to commonly used glass and carbon fibers, BF has higher tensile strength than glass fibers and higher elongation at break than carbon fibers [10]. There are various studies carried out for BF usage in conventional concrete, however, studies about SCC with BF are limited. *Algin & Ozen* investigated properties of SCC reinforced with BF. Researchers examined different lengths and dosages of BF in SCC and concluded that 0.5% fiber content and 24 mm fiber length provided a 19% increase in flexural strength [11]. *Rohilla et al.* studied on different fibers for reinforcing SCCs. It was reported that %0.25 content of BF improved the mechanical properties of SCC. At 28th day, compressive, flexural and split tensile strength are increased at the rate of %50.16, %61.74 and %24.56, respectively. [12]. *Ponikiewski and Katzer* investigated steel, basalt and polypropylene fiber reinforced SCCs. Authors reported that fibers are useful solutions for improving performance of SCC. However, 5 and 12 mm basalt fibers cause

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decrease on compressive strength at the rate of %11.5 and %31.1, respectively [13]. Studies show that while BF provides improvement on the mechanical properties of SCC, it causes a decrease in its workability properties. Changes in workability and mechanical properties occur depending on the dosage, aspect ratio and other properties of the fiber.

In this study, the effect of the change in aspect ratio of the commonly used basalt fiber on the mechanical and workability properties of SCC was examined. SCC samples prepared with 4 different aspect ratios were compared with the reference sample. Slump flow, V funnel, compression, flexure and split tensile tests were carried out and result were discussed. While various studies on the use of BF in conventional concrete were presented, there are deficiencies regarding the use of SCC with basalt fiber. Therefore, this study aims to fill this gap.

2. MATERIAL AND METHODS

2.1. Materials and Mixture Design

CEM I 42.5 R Portland cement was utilized in mixture design in compliance with TS EN 197/1 standard [14]. The chemical, mechanical and physical features of used cement (CEM I 42.5 R) were listed in Table 1. The water-cement ratio was constant at 0.4 in the reference sample and other samples with basalt fiber additives. 1.6% superplasticizer were used in all specimens. basalt fiber was used with the ratio of 0.75% of total volume. The mixing ratios of reference and fiber samples are presented in Table 2. "R" represents reference specimen, other SCC specimens numbered with their aspect ratios (AR). For each type of experimental parameter, 3 samples were prepared and tested. Their averages were calculated and evaluated as results.

Table 1. Properties of CEM I 42.5 R Portland Cement

Chemical properties (%)		Physical and mechanical properties	
SO3	2.84	Initial setting time (min.)	137
MgO	3.76	Final setting time (min.)	179
CaO	62.96	2-days compressive strength (MPa)	25.4
SiO2	17.99	28-days compressive strength (MPa)	51.8
K2O	0.35	Specific gravity (g/cm3)	3.12
Na2O	0.17	Specific surface (cm2/g)	3674
Al2O3	4.43		
Fe2O3	3.35		
Cl-	0.0211		

Table 2. Mix Design Proportions

Mixture Codes	Cement (kg/m^3)	Water (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)	W/C	Superplasticizer (%)	BF Fiber Volume (%)
R	480	192	690	470	0.4	1.6	0
SCC-AR-430	480	192	690	470	0.4	1.6	0.75
SCC-AR-560	480	192	690	470	0.4	1.6	0.75
SCC-AR-855	480	192	690	470	0.4	1.6	0.75
SCC-AR-1145	480	192	690	470	0.4	1.6	0.75

In this study, the effect of fiber aspect ratio in SCC was examined. Basalt fibers with different lengths were used in the prepared samples, while keeping the fiber diameter constant. Since basalt fiber is added to the concrete volumetrically, as the aspect ratio increases, the volumetric fiber amount in the concrete remains constant, but the amount of fiber per unit volume decreases. The tensile strength of the basalt fiber is 4840 MPa. The fiber lengths and aspect ratios of basalt fiber added specimens were presented in Table 3, and an image of the fiber is presented in Figure 1.

Table 3. Fiber Lengths and Aspect Ratios of Mixtures

Mixture Code	Fiber length (mm)	Aspect Ratio
SCC-AR-430	6	430
SCC-AR-560	8	560
SCC-AR-855	12	855
SCC-AR-1145	16	1145

Figure 1. Basalt fibers

2.2. Methods

2.2.1. Slump flow and V funnel tests

Fresh concrete properties were tested with slump flow and V funnel tests. Slump flow test carried out according to standard of TS EN 12350-8 [15], V funnel test carried out according to TS EN 12350-9 [16].

2.2.2. Compressive, flexural and splitting tensile strength

Hardened concrete tests (compression, flexural and splitting tensile) were carried out in accordance with TS EN 12390-3[17],12390-5 [18] and 12390-6 [19] standards respectively. Cube samples with dimensions of 150x150x150 mm were prepared for compression and splitting tensile tests, and 40x40x160 mm rectangular samples were prepared and tested at the age of 28 days. The experimental setups are presented in Figure 2.

Figure 2. Compression and flexural test

3. RESULTS AND DISCUSSION

3.1. Fresh Concrete Properties

V – funnel and slump flow tests were performed for investigate fresh concrete properties of specimens. Slump flow tests results were presented in Figure 3. Spread diameter of reference specimen was 269 mm. Basalt fiber addition decreases the spread diameter of SCC compared with the conventional SCC. The increase in basalt fiber aspect ratio also increases the spreading diameter. When the aspect ratio is increased by keeping the fiber volume constant in the mixture, the amount of fiber per unit volume decreases. Therefore, as the aspect ratio increases, workability and concrete consolidation increases.

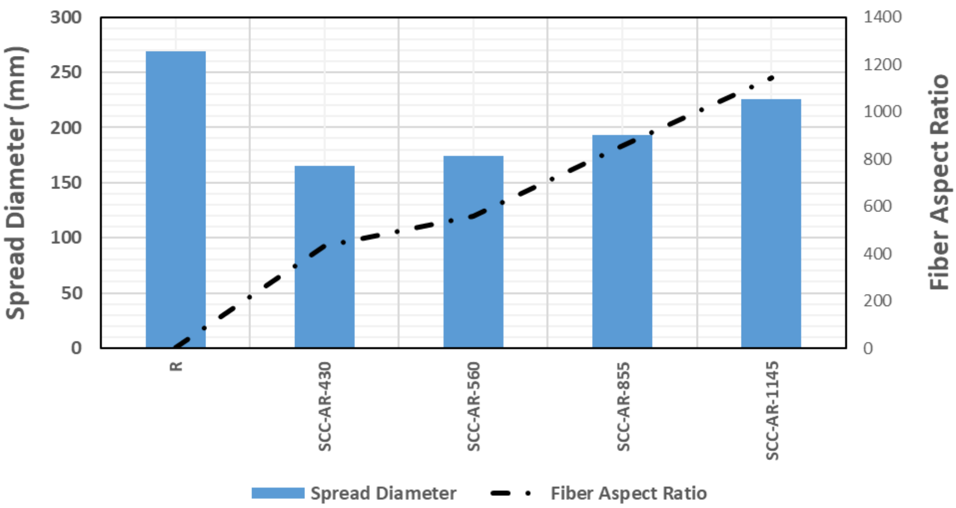

Figure 3. Slump Flow Test Results

Results of V funnel test are shown in Table 4. The results observed in the V funnel test are at an acceptable level between 9-25 seconds according to TS - EN 12350-9. For this reason, the results obtained in this work are acceptable. Increasing the fiber aspect ratio decreases the flow time. The SCC-AR-1145 sample provided a flow time (12.4 s) value close to the reference sample (11.6). This can be explained by the increase in workability as a result of the decrease in the amount of fiber per unit volume as the aspect ratio increases.

Table 4. V – Results of V Funnel Test

Specimens	V-Funnel (s)
R	11.6
SCC-AR-430	19.2
SCC-AR-560	17.3
SCC-AR-855	14.7
SCC-AR-1145	12.4

3.2. Hardened Concrete Properties

In this section, compressive, flexural, and splitting tensile strengths are presented. Compressive strength test results are presented in Figure 4. The compressive strength of the reference sample is higher than all other samples on the 7th and 28th days. The addition of basalt fiber caused decrease in compressive strength in comparison with the reference sample. However, increasing the aspect ratio also caused an increase in compressive strength. The 28th day compressive strength of the SC-AR-1145 sample decreased by 3.24% in comparison with the reference sample.

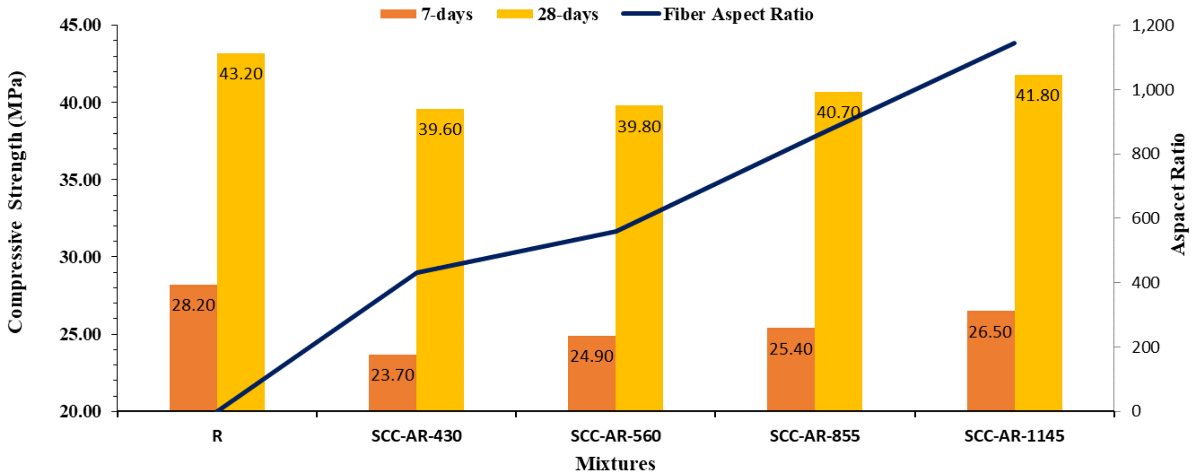

Figure 4. Results of Compressive Strength Test

Flexural strength results were presented in Figure 5. It is expected that adding fiber to concrete will affect the flexural strength more than the compressive strength. When the results were examined, the flexural strengths of all samples increased comparison with the reference sample. Additionally, increasing the aspect ratio also increased the flexural strength. As the aspect ratio increases, the interaction surface of basalt fibers with cement increases, so the flexural strength also increases due to increased adherence.

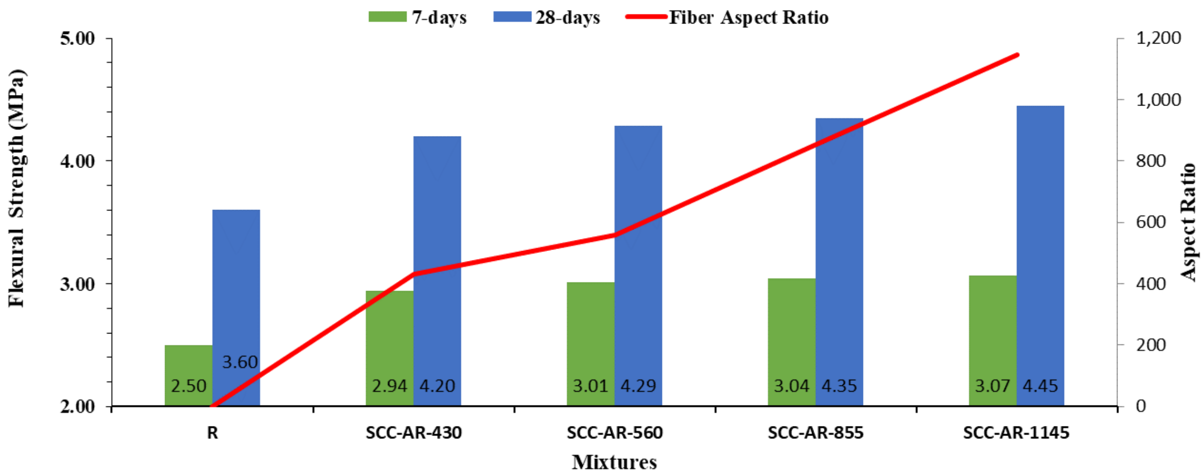

Figure 5. Flexural Strength Test Results

Splitting tensile strength results were presented in Figure 6. The splitting tensile strength of all samples with added basalt fiber is higher than the reference sample. The increase in aspect ratio had a slight effect on the increase in splitting tensile strength. While the reference sample has a strength of 3.65 MPa, the SCC-AR-430 sample has a strength of 4.17 MPa and the increase rate is 14.25%. While the strength of the SCC - AR - 430 sample is 4.17 MPa, the strength of the SCC - AR - 1145 sample is 4.41 MPa and the increase rate is 5.76%.

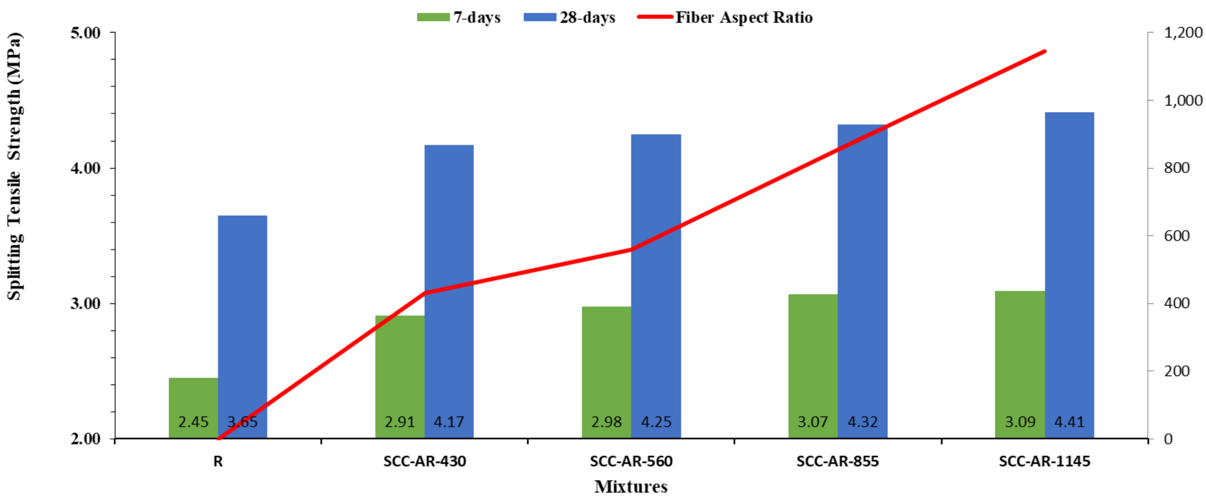

Figure 6. Splitting Tensile Strength Test Results

4. CONCLUSIONS

In this study, the effect of the aspect ratio of basalt fibers on the workability and mechanical properties of SCC was investigated. The SCC prepared as a reference and basalt fiber added SCCs with different aspect ratios were examined comparatively. Basalt fibers with 4 different aspect ratios were used, and these values are 430,560,855,1145. Slump flow, V tunnel, compression, flexural and splitting tensile strength tests were carried out. The results can be drawn as follows:

- Adding fiber to the SCC will increase the adherence and thus reduce the slump spread diameter values. SCC-AR-1145 sample has the closest slump value to the reference sample, while its spreading diameter is 15.99% lower than the reference sample. It is 36.97% higher than the SCC-

AR- 430 sample. Since basalt fiber is added to the concrete volumetrically, as the aspect ratio increases, the volumetric fiber amount in the concrete remains constant, but the amount of fiber per unit volume decreases. Therefore, as the aspect ratio increases, workability and concrete settlement increases. However, the compressive strength decreased in all samples compared to the reference.

- Increasing the basalt fiber aspect ratio caused an increase in compressive strength. However, in all BF added SCCs, concrete compressive strengths decreased in t comparison with the reference SCC. The compressive strength at 28^{th} day of the SCC - AR -1145 sample has the closest value to the reference sample. SCC-AR-1145 specimen's compressive strength was 3.2% lower than the reference sample. Agglomeration had an effect on the lower compressive strength of all fiber-added samples compared to the reference sample.
- Flexural strength increased with increasing fiber aspect ratio. From the sample with the lowest aspect ratio to the highest, there was an increase of 16.67%, 19.17%, 20.83%, 23.61%, respectively, compared to the reference sample at 28^{th} day. As the aspect ratio increases, the interaction surface of basalt fibers with concrete increases, so the bending strength also increases due to increased adherence.
- The tensile strength in splitting increased depending on the increase of the aspect ratio. The highest increase was recorded in the SCC-AR-1145 sample, with a 20.82% increase compared to the reference sample.
- Since studies examining the effects of basalt fiber and aspect ratio on the mechanical properties of SCC are limited, this study plays an important role for future studies and more effective usage of fiber to enhance performance of concrete.

Declaration of Ethical Standards

Authors declare that all ethical standards have been complied with.

Declaration of Competing Interest

The authors declare no conflict of interest.

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Data Availability

No data was used within this study.

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