

# Effect of Quartz Sand on Compressive Strength of High Performance Basalt Fiber Concrete

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**Abstract.** The QS with different sizes was used to prepare the HPBFC according to the closing packing theory. The universal mechanical tester was applied to test the compressive strength of HPBFC specimens after different curing periods. Effects of the QS with different sizes and mixing ratios on compressive strength of the HPBFC were compared and the development of compressive strength of the HPBFC during different curing time was analysed. Results show that the QS with small particle size can significantly increase the compressive strength of HPBFC. The HPBFC with small size of QS not only possesses the highest compressive strength at different curing stages, but also has the fastest increasing rate during the standard curing conditions.

## 1. Introduction

High performance concrete (HPC) has been developed for more than 20 years, which is primarily used in many large structures, especially high-rise buildings and long-span bridges for its characters of high strength, high performance and multi-function [1]. In order to meet the engineering requirements, fiber is often used to improve the crack resistance and toughness of HPC. Basalt fiber, as a silicate fiber, is naturally compatible with cementitious composites and often is used to prepare high performance basalt fiber concrete (HPBFC) which possesses higher tensile and compressive strength than ordinary concrete [2].

Sand, as the largest part of HPBFC, can obviously influence the mechanical property, alkali aggregate reaction, volume stability and durability of HPBFC due to its different particle size, shape and elastic modulus [3]. Therefore, the properties of sand cannot be ignored in HPBFC. It is known that the commonly used sand in HPBFC is river sand (RS), dune sand, crushed sand or quartz sand (QS), etc. Compared with other types of sand, QS is harder to be weathered and has better chemical stability under alkaline conditions, which can improve the strength and durability of concrete.

Many experiments have been carried out to study the influence of QS on performance of HPC. Ma et al. found that QS could improve the distribution and compressive strength of concrete and decrease the density of cementitious composites linearly with the rising content of QS [4]. Wang et al. used QS as concrete reinforcement agent and found that QS could improve the impermeability and salt-frost resistance of self-repairing concrete [5]. The results of He et al. showed that quartz powder increased compressive strength of reactive powder concrete [6]. Most of the existing studies investigated the QS with a certain size on properties of HPC. However, few of them studied the QS with different sizes and mixing ratios on the performance of HPC, especially on that of HPBFC.



In this paper, the QS with different sizes was used to prepare the HPBFC according to the closing packing theory. The universal mechanical tester was applied to test the compressive strength of HPBFC specimens after different curing periods. Effects of the QS with different sizes and mixing ratios on compressive strength of the HPBFC were compared and the development of compressive strength of the HPBFC during different curing time was analysed.

## 2. Experiments

### 2.1. Materials

The P.O 52.5 Portland cement was produced in Tangshan Jidong Cement Co., Ltd. The technical index of the cement is shown in Table 1.

**Table 1.** Technical index of P.O 52.5 Portland cement

	National standard	Measured value
Loss of ignition/%	$\leq 5.0$	1.01
Specific surface area/( $\text{m}^2/\text{kg}$ )	$\geq 300$	416
Condensation	Initial setting	105
time/min	Final setting	350
3day flexural strength/MPa	$\geq 4.0$	6.0
3day compressive strength/MPa	$\geq 23.0$	31.1
28day flexural strength/MPa	$\geq 7.0$	9.0
28day compressive strength/MPa	$\geq 52.5$	59.8

The fly ash was produced in Lingshou Danxu Mineral Products Processing Plant. The technical index of the fly ash is shown in Table 2.

**Table 2.** Composition of fly ash

Composition	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	Na <sub>2</sub> O
Measured value /%	58	30	4.3	1.5	2.8	3.2

The silica fume was produced in Lingshou Erping Mineral Products Processing Plant. The technical index of silica fume is shown in Table 3.

**Table 3.** Technical index of silica fume

Test items	Test result
Average particle size/ $\mu\text{m}$	0.1~0.3
Specific surface area/( $\text{m}^2/\text{g}$ )	20~28
Refractoriness/ $^{\circ}\text{C}$	$\geq 1600$

The short-cut basalt fiber was produced in Wuhan Hengchida New Material Co., Ltd. The technical index of the short-cut basalt fiber is shown in Table 4.

**Table 4.** Short-cut basalt fiber (for cement concrete)

Test items	Standard requirements	Measured average value
Diameter/ $\mu\text{m}$	9~25	14.09
Fracture Strength/MPa	$\geq 1200$	1988
Elongation at break/%	$\leq 3.1$	2.4
Density/( $\text{g}/\text{cm}^3$ )	2.60~2.80	2.64

The polycarboxylate super-plasticiser was produced in Changchun Dehai Building Materials Co., Ltd. The technical index of polycarboxylate super-plasticiser is shown in Table 5.

**Table 5.** Technical index of polycarboxylate superplasticiser

Product model	Water reduction rate/%	Bleeding rate /%	Air content /%	7day strength ratio/%	28day strength ratio/%	Shrinkage /%	Cement paste fluidity /mm
HK-1	≥25	≤60	≤6.0	≥150	≥140	≤110	≥240

The QS with size less than 1mm and 1-2mm were used in test, which was produced in Lingshou Zhenling Mineral Products Processing Plant. The technical index of QS is shown in Table 6.

**Table 6.** Technical index of quartz sand

Test items	Standard requirements	Measured value
Silica content/%	>96	99.5
Ferric Trioxide Content/%	<0.06	0.012
Mud content/%	<0.2	0.01
Loss of ignition/%	<0.4	0.1
Density/(g/cm <sup>3</sup> )	≥2.55	2.64

## 2.2. Mix proportion

The QS with particle sizes of less than 1 mm and 1-2 mm were selected for this paper. The total amount of QS was the same as RS(1220 kg/m<sup>3</sup>), and the ratio of QS with particle size of less than 1 mm and 1-2 mm was 10:0, 8:2, 7:3, 6:4 and 5:5, which was numbered from 1 to 5, respectively. The detailed design mix proportion of HPBFC is summarized in Table 7.

**Table 7.** Experiment mix proportion of the HPBFC /(kg/m<sup>3</sup>)

Cement	Fly ash	Silica fume	Basalt fiber	Water	Super plasticiser	Quartz Sand		Number
						<1mm	1-2mm	
760	110	130	2	190	30	1220	-	1
						976	244	2
						854	366	3
						732	488	4
						610	610	5

## 2.3. Experiment procedures

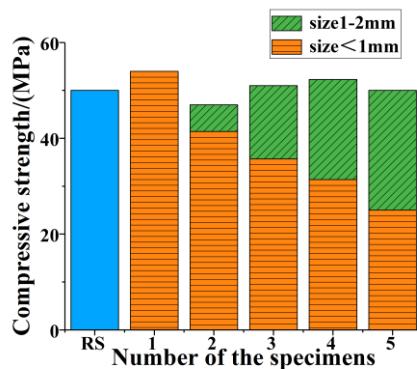
Firstly, the powder material and RS or QS were dried stirred by planetary mixer at a speed of 140 rpm for 1 minute. Secondly, put basalt fibers in the blender and then the materials were stirred for 1 minute. Finally, after adding water and super-plasticiser in the blender, the materials were wet stirred at a speed of 285 rpm for 2 minutes. The dimension of compressive strength test specimens was 150mm×150 mm × 150 mm cube. The specimens were cured in the standard curing room for 3 days, 7 days and 28 days respectively. The compressive strength test was carried out according to the cubic compressive strength test method (ASTM C39 / C39M-18).

## 3. Results and Discussion

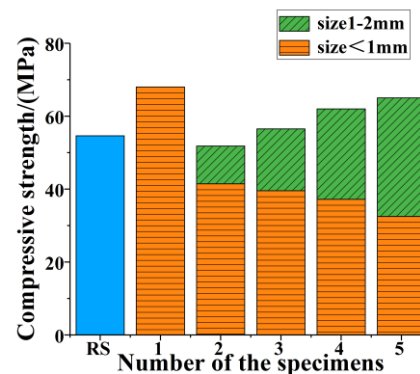
### 3.1. Effect of quartz sand with different particle sizes and mixing ratios on compressive strength of HPBFC

The compressive strength of different HPBFC cured for 3days is shown in figure 1. The specimen of no.1 has the highest compressive strength, which can reach 54MPa, while the compressive strength of no. 2 is the lowest at 47MPa. The overall trend of compressive strength is on the rise as the increasing

ratio of QS with larger size, for example, the specimens of no. 3 and no. 4 are 51MPa and 52.3MPa, respectively.

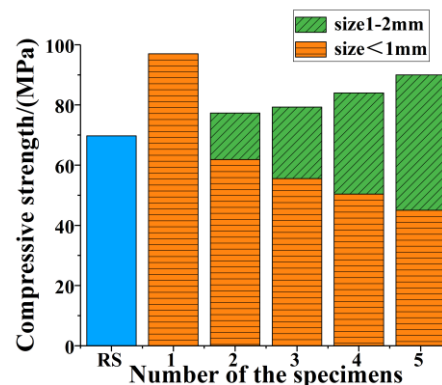


**Figure 1.** 3 days compressive strength of the HPBFC.



**Figure 2.** 7 days compressive strength of the HPBFC.

Figure 2 shows the measured compressive strength of HPBFC after cured for 7 days. The compressive strength of HPBFC with RS is 54.6MPa. The specimen of no. 1 has the compressive strength at 68MPa, which is much higher than that of HPBFC with RS. However, after mixed with larger size of QS, the compressive strength of the HPBFC shows a decreasing trend compared with the HPBFC with only small size of QS. The more the larger size of QS is contained, the higher the compressive strength of HPBFC is. The specimen of no. 1 has the highest compressive strength at 54MPa and the specimen of no. 2 owns the lowest compressive strength at 47MPa. Cohesion between of cement and aggregate increase rapidly in the early stage by increasing the specific areas of aggregate, so the QS with particle size less than 1 mm is advantageous to the early strength of concrete.



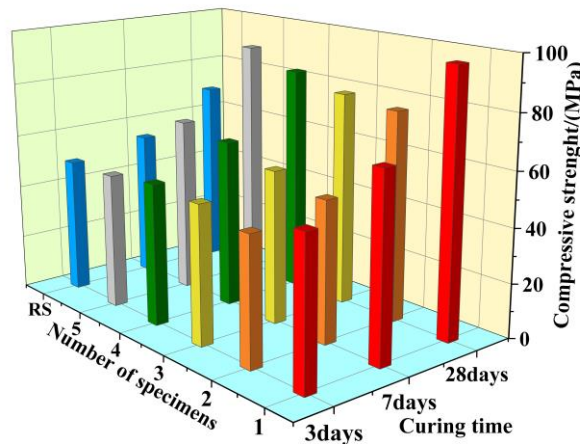
**Figure 3.** 28 days compressive strength of the HPBFC.

As shown in figure 3, the compressive strength of specimen no. 1 is 97MPa, which is higher than that of the RS control group of 69.7MPa. As the increase of the QS with larger size, the compressive strength of the specimens increases gradually. However, the compressive strength of specimens with larger size of QS are all smaller than that with only small size of QS (less than 1mm), which is in agreement with the results in figures 1 and 2. This indicated that the QS with small particle size can significantly increase the compressive strength of HPBFC.

### 3.2. Effect of curing time on compressive strength of HPBFC

The effect of curing time on compressive strength of HPBFC by using different proportion of QS is shown in figure 4. As shown in figure 4, the compressive strength of all samples increase with the rise of curing time. However, the increasing rate of compressive strength for different samples is diverse to some extent. Compared with 3 days compressive strength, the 28 days compressive strength of

different specimens (RS, no. 1, no. 2, no. 3, no. 4 and no. 5) increase by 39.4%, 79.6%, 64.4%, 55.4%, 60.6%, 73.1%, respectively. This indicates that the HPBFC with small size of QS not only possesses the highest compressive strength at different curing stages, but also has the fastest increasing rate during the standard curing conditions.



**Figure 4.** Compressive strength of HPBFC at different curing time.

#### 4. Conclusions

- (1) The QS with small particle size can significantly increase the compressive strength of HPBFC, which can be ascribed that the cohesion between of cement and aggregate increase rapidly by increasing the specific areas of aggregate.
- (2) The HPBFC with small size of QS not only possesses the highest compressive strength at different curing stages, but also has the fastest increasing rate during the standard curing conditions.

#### Acknowledgements

This work is supported by the Transportation Science & Technology Project of Jilin Province (2015-1-6, 2017-1-7), the Fundamental Research Funds for the Central Universities (300102219216). The authors gratefully acknowledge their financial support.

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