Effect of Dipping Basalt Fiber on Mechanical Properties of Concrete

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Abstract. A new dipping basalt fiber reinforced concrete (DBF-RC) was developed in this study. The surface of fiber was modified by dipping into epoxy resin. The mix of DBF was first researched on cement mortar, and then on concrete. The workability and mechanical properties of cementitious materials were investigated. Experimental results show that the optimum proportion of DBF is 1%, and with this mix, the compressive strength, flexural strength and flexural toughness of concrete can be improved effectively.

Introduction

Concrete properties such as compressive strength, flexural strength, elastic modulus etc., are important in the service of structures. However, common concrete usually does not meet these requirements. For example, the highway bridge is expected to heavy compression and strong tension, resulting in cracks of concrete and the danger of life [1, 2].

Fiber reinforced concrete (FRC) has superior mechanical properties with high performance fibers and low cost additives, which has been demonstrated by many researchers [3-5]. The addition of fibers in the concrete improves the fatigue resistance, flexural strength, toughness and tensile strength, as well as controls cracking [6]. Furthermore, the addition of fibers can reduce the overall cost of concrete production.

Basalt fiber is a fiber-material composed of minerals plagioclase, pyroxene, and olivine. It has good physical and mechanical properties of tensile strength, elastic modulus etc. But the price of basalt fiber is lower than other fibers. Due to the excellent properties, it is widely used in the areas of high pressure vessels, loading bearing profiles, concrete reinforcement etc.

Recent researches have used the basalt fiber to reinforce the mechanical properties of concrete [7, 8]. However, the mixing basalt fibers are not dispersed well and also reduce the fluidity of concrete, due to its affinity with water. In addition, the bonding between fiber and concrete is still required to improve.

This paper prepared a fiber reinforced concrete using basalt fiber dipped with epoxy resin. The effect of dipping basalt fiber on the workability, compressive strength and flexural strengths of cementitious materials was researched.

Experimental

Materials. The experimental basalt fiber has a diameter of 15 μm and a length of 12 mm, which indicates a large ratio of length to diameter. In addition, the fiber has good physical and mechanical properties, such as flexural strength, elastic modulus, ultimate elongation etc. More information about the properties of basalt fiber (BF) is listed in table 1.

Table 1. The physical and mechanical properties of basalt fiber.

Materials	Diameter (μm)	Length (mm)	Flexural strength (GPa)	Elastic modulus (GPa)	Ultimate elongation (%)
Basalt fiber	15	12	4..2~4.8	93~110	3.1

The fiber had been dipped in epoxy resin to form a dipping basalt fiber (DBF) before experiment. The epoxy resin coating is hydrophobic, which can reduce water. In addition, the surface of the

DBF is smoother than BF, making the fibers be easily mixed in concrete. Thus, with the dipping treatment, the workability and dispersion of fiber is improved. A comparison of the dispersion between BF and DBF is shown in Fig. 1. Furthermore, the coating enhances the flexural strength of fiber and improves the bonding strength with concrete.

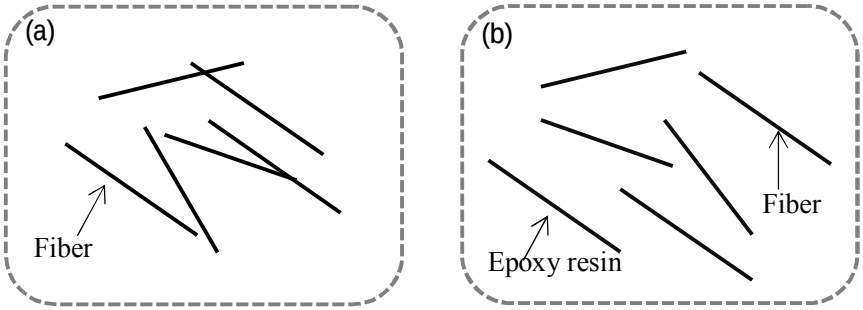

Fig. 1. Schematic diagram of the dispersion of (a) BFand (b) DBF in water.

A Portland cement (C 42.5)) produced by the Huaxin Cement Co. Ltd. was used in the experiment. The secondary fly ash was used as mineral admixture. The fine aggregate had the fineness modulus of 2.8 with the bulk density of 1450 kg/m^3. The diameter of coarse aggregate was 5~31.5 mm.

Mixing Proportions and Forming. A water to cement (w/c) ratio of 0.5 was used for forming cement mortar. The mass ratio of cement: fly ash: sand was equal to 360 g: 90g: 1350 g. The size of mortar for compressive and flexural tests was 40 mm x 40 mm x 160 mm.

The mix proportion of concrete is illustrated in table 2. A polycarboxylic acid was used for reducing water. The size of concrete for compressive test was 100 mm x 100 mm x 100 mm. While that for flexural test was 100 mm x 100 mm x 400 mm.

Table 2. Mix proportion of concrete (kg·m^{-3}).

Cement	Fly ash	Fine aggregate	Coarse aggregate	Water	Water reducer
300	100	733	1146	148	4

Methods of Testing. The fluidity of cement mortar was obtained according to the GB/T 2419-2005. Mechanical properties of compressive and flexural strengths were both investigated on mortar and concrete. Further research on the flexural property of concrete was done by flexural toughness test (Machine, Instron Model 1341).

Results and Discussion

Effect of DBF on Cement Mortar. Due to the similarity of composition and structure between mortar and concrete, cement mortar is in a sense a kind of fine aggregate concrete. Basic researches of the effect of dipping basalt fiber on mortar were done firstly before the mixing of DBF in concrete. Cement mortars with different DBF ratios of 0.5%, 1%, and 1.5% were prepared, respectively. The curing age of cement mortars was 7 days.

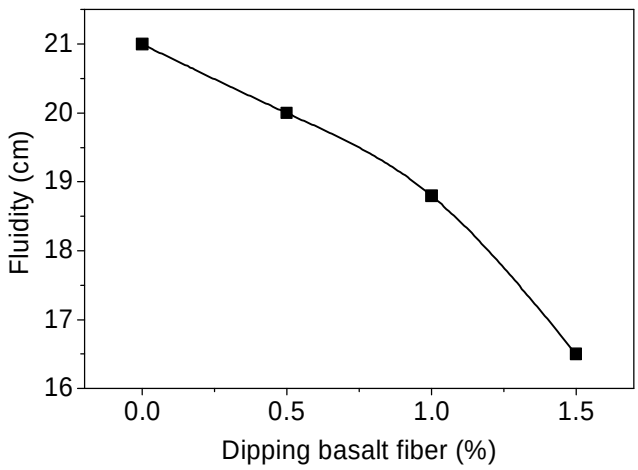

Fig. 2. Effect of DBF on the fluidity of cement mortar.

As shown in Fig. 2, the fluidity of cement mortars was decreased after mixed with DBF. The fluidity is in inverse proportion with the ratio of DBF. For the ratio of 1.5%, the fluidity was decreased greatly. While mechanical properties of cement mortars were obviously improved, this is illustrated in Fig. 3. Considering both workability and mechanical property, the DBF ratio of 1% is proper for use.

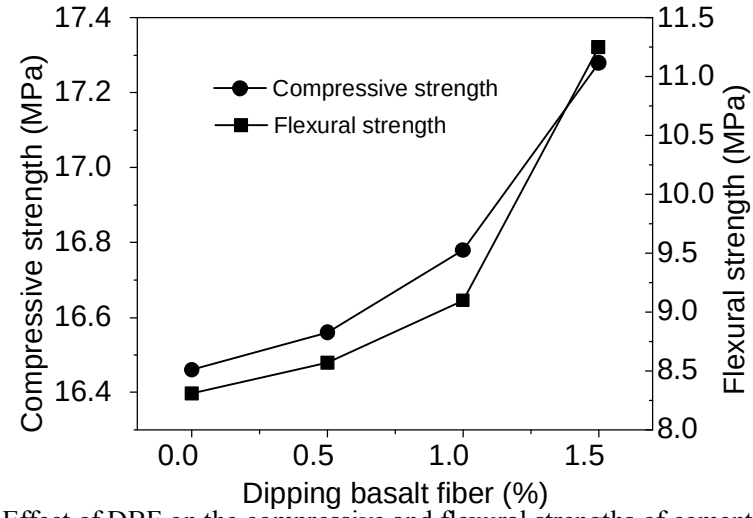

Fig. 3. Effect of DBF on the compressive and flexural strengths of cement mortar.

Based on the study of mortar, the mixing proportion of 1% was chosen to form a dipping basalt fiber reinforced concrete (DBF-RC). And then the mechanical properties of DBF-RC would be researched.

Compressive and Flexural Strengths of DBF-RC. A normal concrete and DCF(1%) reinforced concrete (DBF-RC) were compared in this research. The compressive and flexural properties were investigated at the curing ages of 3 d, 7 d and 28 d.

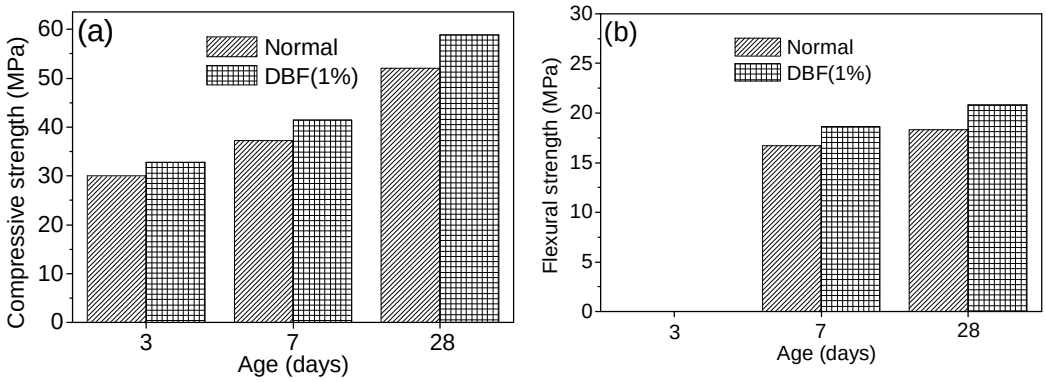

Fig. 4. Influence of DBF on (a) compressive and (b) flexural strengths of concrete

As depicted in Fig. 4, compared with the normal concrete, the compressive strength of DBF-reinforced concrete was increased by 8.7%, 10.1% and 13.3% at the ages of 3 d, 7 d and 28 d, respectively. The 3 d flexural strength was too weak, and was not easy to measure. The flexural strengths of 7 d and 28 d were increased by 11.6% and 14.1%, respectively. The data result shows that DBF has a greater influence on flexural strength than compressive strength.

Flexural Toughness Test. Fig. 5 shows the deflection curves of normal concrete and DBF-RC. The deflection of DBF-RC is 0.476 mm. While for normal concrete is 0.448 mm. Parameters of the flexural toughness are listed in table 3. Compared with normal concrete, the DBF-RC has a higher bearing capacity, and requires more power to be destructed. The elastic modulus data shows the deformability of DBF-RC is better than normal concrete.

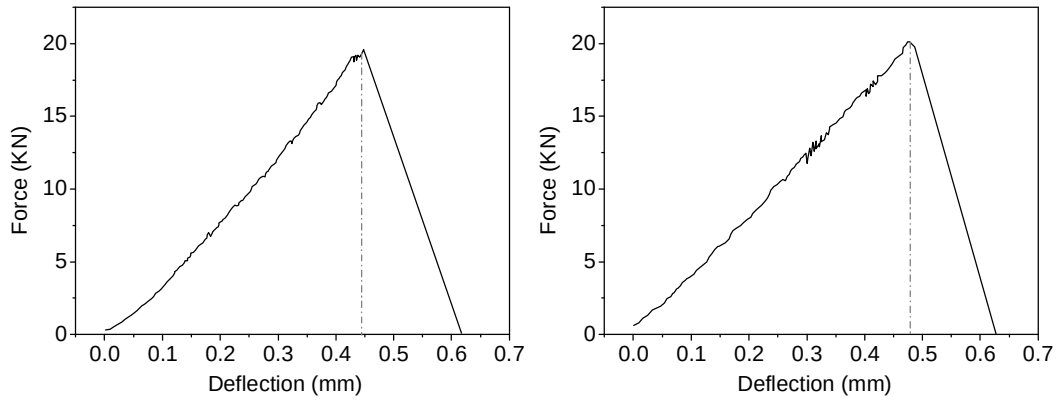

Fig. 5. Influence of DBF on the deflection of concrete.

Table 3. Parameters of the flexural toughness test.

Samples	Max. load (KN)	Max. yield strength (Mpa)	Elastic modulus (Mpa)	Yield power (J)	Destruction power (J)
Normal	16.88	5.06	3305.89	3.39	3.71
DBF(1%)	20.79	6.24	3104.47	6.56	7.85

Conclusions

The effect of dipping basalt fiber on the mechanical properties of cementitious materials was researched in this research. Fibers dipping with epoxy resin have better dispersive and bonding abilities. The optimum proportion of DBF and its influence on mechanical properties of concrete were investigated.

Acknowledgements

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