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Experimental Study on the Tensile Properties of Short-cut Basalt Fiber Concrete

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Abstract: *Improving the tensile, flexural, and shear strength of concrete is always the focus of research because the poor tensile property of concrete is relatively poor. Base on the mechanical performance test of short-cut basalt fiber concrete, the influence of fiber content and fiber length on split tensile strength, flexural strength, and shear strength of basalt fiber concrete were discussed in this paper. With the increase of short-cut basalt fiber content, the split tensile strength and flexural strength were respectively increased by 13.3% and 16.9%, but the shear strength of basalt fiber concrete specimens was lower than reference concrete specimens. With the same fiber content, the monofilament length of short-cut basalt fiber was increased, the shear strength recovered to the level of reference concrete. When the fiber content was 0.1% and the length of the fiber concrete specimens was 12mm, the split tensile strength of the fiber concrete specimen was 13.3% higher than that of the reference concrete specimens. According to the test results, increasing the content and length of fibers could effectively improve the tensile properties of concrete materials.*

Keywords: *concrete, basalt fiber, tensile properties*

1. Introduction

With the rapid development of China's economic growth, some planned civil engineering projects (such as the Hong Kong-Zhuhai-Macao Bridge, etc) have been completed one after another. The planned civil engineering projects are also under preparation, making the consumption of concrete materials increase year by year. Concrete is one of the most widely used building materials in civil engineering. Its compressive performance is relatively great, while its tensile performance is relatively poor. Once the concrete material cracks, it will accelerate the degradation process of the structure, thereby reducing the safety performance and durability of the structure. Therefore, it is necessary to propose effective measures to improve the tensile performance of concrete materials while ensuring compressive performance.

It is shown that adding fiber to concrete can improve the mechanical properties of concrete. In many kinds of fibers, glass fiber-reinforced concrete has poor durability while high application cost of carbon fiber. The high incorporation amount of steel fiber makes its cost high. Basalt fiber as a new type of inorganic reinforcing fiber has received extensive attention. The price of basalt fiber is economical and it has high strength, electrical insulation, corrosion resistance, and high-temperature resistance while being environmentally friendly [1].

Scholars at home and abroad have put forward a variety of methods to improve the mechanical properties of concrete materials through a large number of experimental studies. He Dongqing [2] and Wang Hailiang [3] studied the influence of different basalt fiber mixing on the cracking tensile strength of concrete, and the results showed that with the incorporation of basalt fiber, the cracking tensile strength of concrete has been improved. Dong Jinqiu [4] and Wang Hailiang [3] studied the influence of fiber mixing on the mechanical properties of concrete and concluded that with the increased incorporation amount of basalt fiber, the flexural strength of concrete gradually improved, and the enhancement effect was more obvious. After exceeding a certain mixing amount, the flexural strength decreased, but the strength is still higher than that of plain concrete.

To investigate the effect of short-cut basalt on the mechanical properties of the concrete. In this paper, the split tensile strength, flexural strength, and shear strength of short-cut basalt fiber concrete specimens with different content were tested, and the mechanical properties of the specimens were systematically studied to provide references for engineering practice.

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2. Materials and test methods

2.1. Raw materials and their properties

(1) Cement: The ordinary Portland cement P.O 42.5R was produced by Dalian Xiaoyetian Cement Co., Ltd.

(2) Water reducer: The polycarboxylic acid water reducer was produced by Dalian Mingyuanquan Technology Development Co., Ltd., and its technical parameters are demonstrated in Tab.1. The water reduction rate of the water reducer was 18% and the solid content of the mother liquid of the water reducing agent was 40%, and the mixing ratio of the mother liquid and the aqueous solution was 1:2.

Table 1: Technical parameters of polycarboxylic acid water reducer

Models	PC-1
Chemical composition	The copolymer of polyethylene glycol methyl allyl ether and acrylic acid
Solid content (%)	38 ~ 40
Total alkali content (%)	< 2
Chloride ion content (%)	< 0.1
Sulfate content (%)	< 0.5
PH value	5~7

(3) Fine aggregate: the river sand was provided by the stockyard of CCCC Third Harbor Engineering Co., Ltd. had a fineness modulus of 2.89 and an apparent density of 2600kg/m^3.

(4) Coarse aggregate: the limestone crushed stone from the stockyard of CCCC Third Harbor Engineering Co., Ltd. was used in the test, and its nominal particle size was 5-20mm.

(5) Fiber: short-cut basalt fiber was produced by Shanxi Jintou Basalt Development Co., Ltd. The specification of the fiber used in the test is shown in Tab.2.According to the suggestion of the manufacturer, X2 fiber and its most economical blending amount of 0.1% was chosen as the main research object.

Table 2: Fiber specifications used in the test

Representative symbol	Fiber length (mm)	Fiber monofilament diameter (μm)	Number of filaments per fiber
X1	12	15	200
X2	18	15	200
X3	24	15	200

2.2. Design of mix ratio

The design strength of concrete used in the test was C30. The prerequisite for pumping concrete to meet the pumping conditions is that its slump needs to be ≥180mm in actual civil engineering. In this paper, the design value of the concrete slump was determined to be 180mm. The mixing ratio of concrete used in this paper was demonstrated in Tab.3, where the water-cement ratio was 0.53 and the sand ratio was 0.47. In this paper, a polycarboxylic acid PC-1 type water reducer was used, and the water reducing rate of the water reducer was 18%. Incorporating short-cut basalt fibers would reduce the slump of concrete to a certain extent. Therefore, it was necessary to adjust the mixing content of the water reducer to ensure the workability of concrete during mixing. The content of basalt fiber and water reducer in concrete was demonstrated in Tab.4.

Table 3: Concrete mixing ratio of 1m^3

Material	Stone	Sand	Cement	Water	Water Reducer
Dosage (kg)	986.433	874.762	339.623	180	4.925

Table 4: Fiber and water reducing agent content in concrete

Fiber volume fraction	0.05%	0.1%	0.15%
Fiber content (kg)	1.325	2.650	3.975
PC-1 type water reducing agent dosage (kg)	4.925	5.094	5.434
PC-1 type water reducing agent accounts for the proportion of cementitious materials (%)	1.45	1.5	1.6

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2.3. Methods of tests

The split tensile strength test of basalt fiber concrete was carried out according to the standard GB/T 50081-2019 [5] in this paper, and the size of the concrete specimens was 150mm×150mm×150mm. After dismantling the mold, the specimen is placed in a curing box with a temperature of 20 ℃ and a humidity of 95% for standard curing. The specimens were tested after 28 days of standard curing.

The flexural strength test of basalt fiber concrete was carried out according to the standard GB/T 50081-2019 [5] in this paper. The size of the test specimens adopted the standard flexural test specimens size of 150mm×150mm×550mm, and the test specimens were put into a curing box with a temperature of 20 ℃ and humidity of 95% for standard curing after the mold was removed. After 28 days of standard curing, the specimens were tested.

The shear performance test of basalt fiber concrete was carried out by the standard CECS13: 2009 [6] in this paper. The test method adopted the double-sided direct shear method, and the size of the test piece was designed to be 100mm×100mm×300mm. The specimens were placed in a curing box with a temperature of 20 ℃ and a humidity of 95% for standard curing after mold removal. After 28 days of standard curing, the specimens were tested.

3. Analysis and results

3.1. Split tensile test

The split tensile strength results of basalt fiber concrete were obtained, as demonstrated in Ta.5.The symbol T represents the split tensile strength test. The test results demonstrated that the content of short-cut basalt fiber increased from 0.05% to 0.15%, and the split tensile strength of basalt fiber concrete was increased by 13.3%. When the fiber content was 0.1% and the length of the fiber concrete specimens was 12mm, the split tensile strength of the fiber concrete specimen was 13.3% higher than that of the reference concrete specimens.When the length of the fiber-reinforced concrete specimen was 24mm, the split tensile strength of the fiber concrete specimens was increased by 3.3% compared with the reference concrete specimens.

Table 5: Test results of split tensile strength

serial number	Fiber content	Split tensile strength (MPa)	Growth rate (%)
T-X0	/	3.0	/
T-X1	0.1%	3.4	13.3
T-X2	0.05%	3.1	3.3
T-X2	0.1%	3.2	6.7
T-X2	0.15%	3.4	13.3
T-X3	0.1%	3.1	3.3

3.2. Flexural strength test

Table 6: Test results of flexural strength

serial number	Fiber content	Flexural strength (MPa)	Growth rate (%)
B-X0	/	5.0	/
B-X1	0.1%	5.7	14.9
B-X2	0.05%	5.8	16.9
B-X2	0.1%	5.3	6.0
B-X2	0.15%	5.4	9.1
B-X3	0.1%	4.5	-9.1

The flexural performance test results of basalt fiber concrete were obtained, as demonstrated in Tab.6. The symbol B represents the flexural performance test. According to the test results, the content of short-cut basalt fiber was increased from 0.05% to 0.15%, and the flexural strength of basalt fiber concrete increased by 16.9%, 6.0%, and 9.1%, with an average increase of 10.7%. When the fiber content was 0.1% and the short-cut basalt fiber was 12mm, the flexural strength of the fiber concrete specimens was increased by 14.9% compared with the reference concrete specimens. When the length of the short-cut basalt fiber was 24mm, the flexural strength of the specimens was 9.1% lower than that of the reference concrete specimens. The deviation of the concrete specimens No.B-X3 was relatively large, and the possible reason was speculated: the mold for pouring the concrete specimens had problems so that the upper and lower surfaces of the specimens were not parallel after pouring, it made the concrete specimens bear eccentric compression during the test, which caused problems with the results.

3.3. Shear strength test

The results of the basalt fiber concrete shear performance test were obtained, as demonstrated in Tab.7. The symbol S represents the flexural performance test. The test results demonstrated that the content of short-cut basalt fiber increased from 0.05% to 0.15%, and the shear strength of basalt fiber concrete was reduced by 15.7%, 7.0%, and 0.6%. When the fiber content is 0.1% and the length of short-cut basalt fiber was 12mm, the flexural strength of the fiber concrete specimen is 5.0% lower than that of the reference concrete specimen; when the length of the short-cut basalt fiber is 24mm, the flexural strength of the fiber concrete specimens was 0.6% higher than the reference concrete specimens.

Table 7: Test results of shear strength

serial number	Fiber content	Shear strength (MPa)	Growth rate (%)
S-X0	/	6.4	/
S-X1	0.1%	6.1	-5.0
S-X2	0.05%	5.4	-15.7
S-X2	0.1%	6.0	-7.0
S-X2	0.15%	6.2	-2.5
S-X3	0.1%	6.4	0.6

3.4. Analysis of test results

According to the split tensile test, flexural test, and shearing test, the addition of short-cut basalt fiber had improved the tensile (flexural) process of concrete. Due to the value of the split tensile strength and flexural strength of the specimens is not large, so that the test results have no obvious tendency to change with the increase of fiber content. According to the overall test results, it can be known that the addition of short-cut basalt fiber could effectively improve the crack resistance of concrete materials, which is close to the research results of Lian Jie et al. [7], but the significance is not obvious. For further analysis through the shear test, the addition of short-cut basalt fiber would cause the reduction of concrete shear performance, but with the increase of fiber content and fiber length, the shear strength of concrete specimens returns to the initial level. So it can be inferred that the specification and content of short-cut basalt fiber recommended by the manufacturer (18mm-0.1%) are relatively conservative, and the fiber content could be appropriately increased under the premise of the economy.

4. Conclusion

In this paper, the split tensile test, flexural test and shear test of short-cut basalt fiber concrete specimens with different contents and specifications were carried out. The conclusions obtained are as follows:

(1) The split tensile strength and flexural strength of concrete can be improved as the content of short-cut basalt fiber increases. The shear strength of concrete mixed with short-cut basalt fiber is lower than that of the reference concrete.

(2) The length of the short-cut basalt fiber monofilament would be too short to reduce the mechanical properties of the concrete material when the fiber content is controlled to 0.1%.On the contrary, it can effectively improve the mechanics of the concrete performance when the length of the short-cut fiber monofilament is longer.

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References

[1] Liu Lulu. Experimental study and numerical simulation of basalt fiber beam concrete [D]. Zhengzhou: Zhengzhou University, 2020: 1-3.
[2] He Dongqing, Lu Zhen. Experimental study on the mechanical properties of chopped basalt fiber concrete [J]. Journal of Henan University (Natural Science Edition), 2009, 39(03): 104-106.
[3] Wang Hailiang, Yuan Lei, Song Hao.Study on the mechanical properties of short-cut basalt fiber concrete [J]. Building Structure, 2013 (43): 562-564.
[4] Dong Jinqiu, Du Yanting, Wen Baolian.Study on the mechanical properties and hardening mechanism of basalt fiber concrete [J]. Industrial Construction, 2011, 41 (s1): 637-641.
[5] The standard for test methods of concrete physical and mechanical properties [S]. National Standard of the People's Republic of China, GB/T 50081-2019.
[6] Fibre concrete test method standard [S]. Industry standard-Recommended standards for engineering construction, CECS 13-2009.
[7] Lian Jie, Yang Yongxin, Yang Meng, Zhao Yan.Experimental study on the mechanical properties of chopped basalt fiber reinforced concrete [J]. Industrial Construction, 2007, (06): 13-15