Study on Experimental and Mechanism of Basalt Fiber Concrete Erosion in Sulfuric Acid Environment

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Abstract. In order to study the influence of basalt fiber on properties of concrete, the concrete test block (100mm) containing 0%, 0.05%, 0.1%, 0.2%, 0.3% basalt fiber, was respectively put in sulphuric acid solution of PH=3 for immersion corrosion test. The corrosion development of concrete test blocks with different amount of basalt fibers were followed up and observed, and the variation law of porosity and compressive strength of concrete in different corrosion environments were analyzed. The results of the tests indicate: The acid corrosion resistance and compressive strength of the concrete with 0.1% fiber added in this experiment have been greatly improved. And the basalt fiber can only play its role when the appropriate amount of the fiber was added. In addition, the acid corrosion resistance and compressive strength of concrete specimens with 0.3% content of basalt fiber were not greatly improved or even decreased. This paper would provide some technical support for the engineering application of basalt fibers.

1. Introduction

Acid rain caused by air pollution has a great impact on the ecological environment and buildings, and it can make concrete surface hardened, cement dissolved, hollow and crack appearance, which leads to the decrease of strength, and seriously affects the durability and reliability of concrete engineering. As a new inorganic, green, environmental protection and high-performance fiber material, basalt fiber reasonably mixed in concrete can retain the advantages of concrete compressive strength higher, and greatly increase the tensile, wear resistance, impact resistance and corrosion resistance performance at the same time. The mechanical property and durability of basalt fiber reinforced concrete have been extensively studied by a large number of scholars at home and abroad. Zhang lanfang have studied the 0.05% ~ 0.35% of basalt fiber on the influence of concrete compressive strength, splitting tensile strength and the bending performance [1]. The results of Jalasutram showed that the failure mode of concrete changes from brittleness to ductility, and the splitting tensile strength, flexural tensile strength and flexural toughness increased significantly with the addition of basalt fiber [2]. The study of Shi Liang showed that the long-term effect of sulfuric acid and sulfate on the denudation and strength development of concrete with the low water-binder ratio is significant, and the volume expansion of the specimen is obvious [3]. Wang Ning studied the changes of the morphology, composition, phase and molecular structure of basalt fiber after acid solution erosion [4]. Jin shengji showed that basalt fiber can enhance the ability of concrete to resist freezing and thawing failure under corrosion condition and effectively prolong the service life of concrete under corrosion condition [5]. Hassan M has studied the change of strength of basalt fiber reinforced concrete under alkaline environment and the effect of temperature on the bond property of its material [6]. Dias showed that
when the volume content of basalt fiber exceeds 1.0, the bond between fiber and cement matrix is not close [7]. Afro-z M has shown that the physical properties and durability of modified basalt fibers are superior to unmodified basalt fibers, especially in terms of mechanical properties [8]. Pearson M has studied the long-term chemical corrosion resistance of basalt fiber by means of morphology observation and strength loss rate measurement; the results showed that the basalt fiber has good alkaline resistance, but poor acid resistance [9]. V. Nasir [10], R.L. Jones [11] have studied the acid resistance of basalt fiber and found that the acid resistance of basalt fiber was stronger than glass fiber, and the corrosion was controlled by dissolution and leaching of Fe and Al. It can be seen from the above analyses that there are few studies on the durability of basalt fiber reinforced concrete, especially on acid corrosion resistance. The acid resistance of basalt fiber reinforced concrete is studied by means of the experimental method in this paper and the results can provide technical support for the engineering application of this new material.

2. Experiment program

In order to study the performance of basalt fiber reinforced concrete under sulphuric acid environment erosion, C30 low alkali ordinary Portland cement is used in the test, and the gravel is continuous gradation with a grain diameter of 5 ~ 31.5mm, medium sand and fineness modulus is 2.6 ~ 2.8, and the accumulative density is 1450kg/m3, the water reducing agent is high range poly-carboxylate powder water reducer. The basalt fiber is made of shortcut basalt fiber, and its physical properties are shown in Table 1. And five kinds of concrete with different volume of basalt fiber are designed, which are respectively 0%, 0.05%, 0.1%, 0.2% and 0.3%. (the mix ratio and fiber content are shown in Table 2), the mixing amount of each volume is three blocks, all sizes are 100 mm × 100 mm × 100 mm, the specimens are put into the standard maintenance room of building materials laboratory for 28 days after forming. The pH value of sulfuric acid solution is 3, the total corrosion time is set at 9 months, and every month is one test age, each test age tests a set of corrosion results, including the weight and volume of saturated state, the dry weight, and propagation of corrosion fractures on the surface of the specimen taken. The test of compressive bearing capacity is carried out at 3rd, 6th and 9th month.

### Table 1. Physical properties of basalt fiber

| Type of fiber | Diameter (/μm) | Density (g/cm³) | Length (mm) | Tensile strength (MPa) | Modulus of elastic (GPa) |
|---------------|----------------|----------------|-------------|------------------------|-------------------------|
| Basalt fiber  | 15             | 2.65           | 12          | 3800-4840              | 93.1-110                |

### Table 2. Concrete mixture ratio

| Number | Concrete (/kg·m⁻³) | Fine aggregate (/kg·m⁻³) | Coarse aggregate (/kg·m⁻³) | Water (/kg·m⁻³) | Fiber (/kg·m⁻³) | Water reducer (/kg·m⁻³) |
|--------|-------------------|--------------------------|---------------------------|----------------|----------------|------------------------|
| C1     | 524               | 532                      | 1129                      | 215            | 0              | 5.24                   |
| C2     | 524               | 532                      | 1129                      | 215            | 1.325          | 5.24                   |
| C3     | 524               | 532                      | 1129                      | 215            | 2.650          | 5.24                   |
| C4     | 524               | 532                      | 1129                      | 215            | 5.300          | 5.24                   |
| C5     | 524               | 532                      | 1129                      | 215            | 7.950          | 5.24                   |

3. Experimental process and phenomena

Basalt fiber reinforced concrete (BFRC) test blocks, each mixing ratio is composed of 3 blocks, which were placed in the sulfuric acid solution of PH=3 to carry out erosion tests, the development of surface fractures is as follows:

90-day fracture phenomenon: Visible to the naked eye of fine fractures can be seen on the surface of plain concrete, but there is no obvious change on the surface of other concrete with basalt fiber.

180-day fracture phenomenon: The surface corrosion of plain concrete is the most serious, a large
number of fractures appear on the surface of the test block and become wider, and the edge angles of concrete fall off, but the addition of 0.1% basalt fiber reinforced concrete specimen has no obvious change compared with the previous surface. 270-day fracture phenomenon: It can be seen from Fig. 3 that the plain concrete specimen is seriously damaged, the surface fracture is dense and the width increases, the integrity is very poor, and the edge corner of the block with 0.1% fiber content is cracked and the concrete shedding, there are a lot of thin fractures on the surface of the block with 0.3% fiber content, and a slight fall of concrete in the corner. The erosion experiment of basalt fiber reinforced concrete in sulphuric acid solution shows that: the mix of the appropriate amount of basalt fiber can significantly improve the early fracture resistance of concrete, and the acid corrosion resistance of concrete with basalt fiber is obviously improved.

![Fig.1 Erosion on the surface of the test block after immersion for 90 days](image1.png)

![Fig.2 Erosion on the surface of the test block after immersion for 180 days](image2.png)

![Fig.3 Erosion on the surface of the test block after immersion for 270 days](image3.png)

4. **Experiment results and analysis**

4.1 **Variation of water absorption rate**

The water absorption rate of concrete material depends on the porosity of the concrete material. Therefore, the internal porosity development of basalt fiber concrete under the erosion of sulfuric acid in this test block can be reflected by the change of water absorption rate.

It can be seen from Figure 4 that adding 0.1% basalt fiber to the concrete specimen, the improvement effect of acid corrosion resistance is the most ideal and the acid corrosion resistance is the best. And it can be seen from Figure 5 that the water absorption rate of the specimen increases gradually with the immersion time, and the incorporation of basalt fibers change the pore structure in the concrete, after immersion for 3 months, specimen C3 was reduced by 7.1% compared to the undoped specimen C1, and 0.3% of C5 specimen have the highest porosity, which is 7.3% more than C1. It can be seen that the addition of 0.1% basalt fiber has the most obvious effect on the increase of concrete porosity.
4.2 Compression test

The specimens with erosion up to 3, 6 and 9 months were subjected to compression tests respectively, and the damage loads were recorded. The failure processes of different basalt fiber admixture for 6 months are shown in Figure 6.

The variation of compressive strength with the content of basalt fiber is shown in Figure 7. The compressive strength of C3 specimens is slightly higher than ordinary concrete in the third month with an increase of 6.6%. Compared with the 3rd month, the compressive strength of the C3 specimen increased by 53.5% in the 6th month and 49.16% in the 9th month, while the C2 specimen increased by 30.06% at the same time. Therefore, the addition of basalt fiber can improve the compressive strength of concrete, and it also shows that the acid corrosion resistance of basalt fiber reinforced concrete is improved to some extent. (The words C-3 and C1-3 appeared in the picture, in which C and C1 represent the test block categories, and 3 represents the month of erosion.)

Fig. 8, 9, 10 shows the displacement load curve of the compressive test of each specimen in the 3rd, 6th and 9th. During the loading process, the load-displacement curve of C1 specimen decreases rapidly, the crack develops rapidly, and when the specimen is destroyed, almost no plastic deformation occurred, manifested as an obvious brittle failure. After the specimen of C3 reaches the yield load, the load displacement curve changes slowly, the displacement continues to increase, and the load decreases obviously, showing good ductility.
5. Conclusions
The main research objects of this paper are acid corrosion resistance and mechanical property of basalt fiber reinforced concrete. Through experimental verification and theoretical analysis, some conclusions are drawn, which can be used as a reference for practical engineering application:

1) Appropriate amount of basalt fiber adding can significantly improve the early crack resistance of concrete, and the best anti-cracking effect is when the content is 0.1%.

2) The porosity of basalt fiber reinforced concrete with 0.1% content of basalt fiber is 25% lower than the undoped after 6 months immersion. It can be seen that adding 0.1% basalt fiber has the most obvious effect on the increase and containment of concrete pore.

3) The mix of basalt fiber can effectively improve the failure characteristics of concrete itself and change the failure of concrete from brittle to plastic, when the content of basalt fiber is 0.1%, the compressive strength of the third, sixth and ninth months of erosion increases by 6.6%, 53.5%, 49.16% respectively, compared with the ordinary concrete.

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