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Study on Corrosion Behaviour of Basalt Fibre Reinforced Concrete under NaOH Environment

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Abstract. Basalt fibre (BF) is an inorganic material with high temperature resistance, low temperature resistance, strong acid and alkali corrosion resistance and good compatibility. Addition of BF into the concrete can improve the multiple properties of concrete. The purpose of this paper is to study the durability of basalt fibre reinforced concrete (BFRC) under the alkaline environment and analyse its corrosion mechanism. To this end, in this paper, 20% sodium hydroxide (NaOH) solution was used to simulate the alkaline environment, and the control group of clear water was also set by immersing and corroding the test blocks for 90 days, 180 days and 270 days respectively. Then, the crack propagation, Na⁺ migration, water absorption, and compressive bearing capacity of the test blocks under different corrosion time were analysed and the failure mechanism was discussed. The results show that the addition of BF can effectively inhibit the generation and propagation of concrete cracks; in alkaline environment, the BF can effectively prevent the migration of Na⁺, but its effect decreases with the increase of corrosion time; compared with ordinary concrete, the BF addition in alkaline environment can improve the bearing capacity of concrete to certain degree, but insufficient or excessive addition will adversely affect the durability of concrete. Through the comprehensive analysis, when the BF content is 0.1%, the porosity, durability and compression bearing capacity of concrete are improved most obviously.

1. Introduction

Basalt Fibre Reinforced Concrete (BFRC) is made by mixing certain proportion of basalt fibre into ordinary concrete. The incorporation of BF can improve the tensile strength and compressive strength of concrete, limit the cracks propagation, and enhance its durability. Therefore, in recent years, BFRC has performed excellent performance in the construction of civil buildings, bridges, highways, and military facilities etc. With the application of BFRC in engineering, scholars from various countries have begun to study the mechanical properties and durability of BFRC in various environments. Yu Ying [1] et al. conducted an experimental study on the impact resistance of BFRC; the results show that the 6mm short fibre has better effect on the impact resistance of concrete than 18 mm long fibre. Wang Jun [2] found that when the basalt fibre content is 0.1%, the compressive strength reaches the maximum, the tensile strength and flexural strength continue to increase with the increase of fibre



content, and the BP neural network-based strength prediction model is also established. Huang Kaijian [3] studied the mass loss rate of basalt fibre at different concentrations, temperatures and soaking times of alkaline solution, and observed its damage state by the microscope. Li Weimin [4] found that basalt fibre has a certain improvement effect on the impact mechanical properties of concrete; its reinforcement and toughening effect on the concrete is better than carbon fibre. When the fibre content is 0.1%, the basalt fibre has the best effect on enhancing the concrete. Jung Jin Lee [5] et al. studied the chemical stability of basalt fibre in alkaline solution, finding that basalt fibre immersed in weak alkaline solution is very stable and the mass loss rate is low after being immersed in Ca (OH)₂ solution for 3 months. Borhan, TM [6] et al. studied the mechanical properties of glass aggregate concrete after adding basalt fibre, and proposed the optimal fibre addition amount corresponding to different aggregate replacement rates. Mahzabin Afroz [7] et al. studied the durability of modified and unmodified basalt fibres; the fibres were immersed in 12 solutions for 62 days in consideration of the concrete medium environment, and the damage morphology and features of the fibres were observed by SEM. Chen Wei [8] et al. studied the effect of basalt fibre on the crack resistance of concrete beams based on the variation of basalt fibre length and volume; the results show that the cracking load of BFRC beams is significantly improved when compared with ordinary reinforced concrete (RC) beams, and the cracks propagates slowly. Wang Mingchao [9] studied the chemical corrosion resistance of a continuous basalt fibre and its composites. The results show that this fibre and its composites have good water and alkali resistance, and the alkali resistance of the fibre is better than the acid resistance. Li Jian [10] found that the addition of basalt fibre can significantly improve the flexural strength and splitting tensile strength of slag fly ash concrete. The SEM shows that the basalt fibre has good adhesion to the matrix and can effectively inhibit the development of cracks. Zhang Lanfang [11] et al. found that when the fibre content is less than 0.3%, the compressive strength and tensile strength of concrete are improved, and the stress-strain curve of concrete after basalt fibre is added has obvious yield point and crack resistance. John Branston et al. [12] compared the effects of chopped basalt fibre and the reduced basalt fibre polymer rebar (MB) on the mechanical properties of concrete. Wang Xinzong [13] et al. studied the effects of different fibre lengths and dosages on the early cracking performance of concrete. The results show that 18mm is the best crack length and there are the least cracks when the added content is 0.2%. In summary, the research on the durability of basalt fibre and BFRC in alkaline environment was conducted mainly at the short-term time of 3d, 7d, 28d, etc., and the long-time corrosion has been still less studied. In this paper, the mechanical properties and durability of BFRC with long erosion time and different contents were studied by immersion corrosion in NaOH solution. Then, the deterioration mechanism of BFRC in alkaline environment was analysed. This is of positive meaning for the application of basalt fibre concrete.

2. Experiments

2.1. Experimental materials and mix ratio

The experimental materials include P.O42.5 Grade Portland cement; river sand for fine aggregate, 2.6-2.8 fineness modulus; continuous graded gravel 5-31mm for coarse aggregate; and high performance-powder water reducing agent for admixture. The BF performance parameters are shown in Table 1. The concrete mix ratio of the test block is shown in Table 2. The content of basalt fibre (BF) is 0%, 0.05%, 0.10%, 0.20% and 0.3%, respectively, as S1, S2, S3, S4 and S5.

Table 1. Physical and mechanical properties of basalt fiber

Raw materials	Fiber diameter/ μm	Length/mm	Density/(kg/m ³)	Tensile modulus/GPa	Tensile strength/MPa
Basalt fiber	15	12	2650	93.1-110	3800-4840

Table 2. Mix proportion of concrete

Specimen	Cement	Sand	Rubble	Water	Fiber	kg/m ³
						Water-reducing admixture
S1	524	532	1129	215	0	5.24
S2	524	532	1129	215	1.325	5.24
S3	524	532	1129	215	2.650	5.24
S4	524	532	1129	215	5.300	5.24
S5	524	532	1129	215	7.950	5.24

2.2. Experimental methods and processes

According to the General Concrete Mechanics Performance Test Method (GB/T 50081-2002) and the Fibre Concrete Test Procedures (CECS 13-2009), five concrete test blocks were designed with the volume amount of 0%, 0.05%, 0.10%, 0.20%, and 0.30%, and the test block sizes were 100 mm × 100 mm × 100 mm. After the test block was prepared, it was cured for 28 days in a standard environment. When passing the sample strength test, the remaining samples except the control group were immersed in the 20% NaOH solution for 90d, 180d, 270d, so as to observe and shoot the crack propagation and Na⁺ concentration in different parts. Then, the water absorption and compressive capacity were also measured.

3. Experiment phenomena and analysis

3.1. Crack propagation and sodium ion migration

It can be seen from Fig. 1 that after the test block without added BF had been immersed in clear water and NaOH solution for three months, the immersed test block in the NaOH solution was severely corroded, and the crack at the outer edge of the block was wide and the corner concrete was peeled off. However, no obvious cracks were observed on the surface of the water-soaked test block, indicating that the NaOH environment has certain corrosiveness to concrete. Fig. 2 shows clearly that a large number of wide through-cracks appeared in the BF-free concrete after being immersed in the 20% NaOH solution for 6 months, and only a small number of cracks appeared on the surface of the test block added with 0.1% BF. Fig. 3 indicates that when the immersion time reached 9 months, the concrete test block without added BF was completely useless, while the test block with added 0.1% BF still has certain use value.

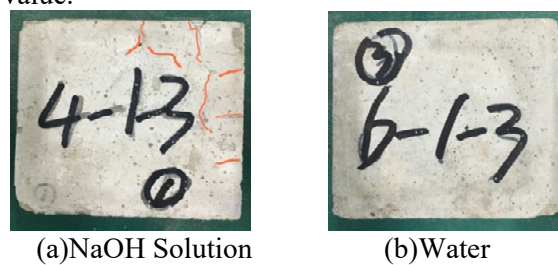


Fig 1. The concrete without BF dip in NaOH solution and water for 3 months

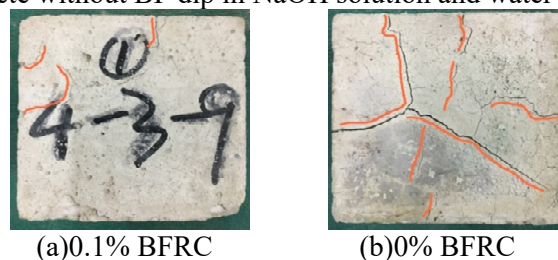


Fig 2. BFRC and concrete dip in NaOH solution for 6 mouths

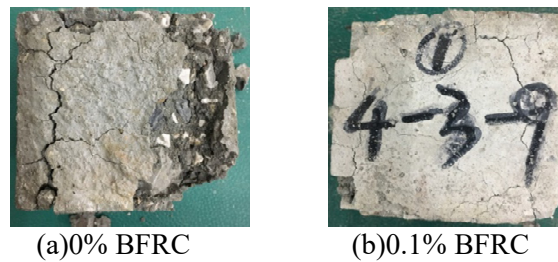


Fig 3. BFRC and concrete dip in NaOH solution for 9 months

In order to further understand the erosive effect of NaOH on concrete, the test block was cut into four pieces from the outside to the inside with a thickness of 10 mm per piece. After grinding, they were dissolved in water and the PNa value of different parts was measured by sodium ion analyser.

Since the test block should be sliced and grinded for Na⁺ measurement, the test blocks used at three time points were not the same, but the change trend of Na⁺ concentration can be seen in the line chart. It can be seen from Fig. 3 to 5 that as the immersion depth increases, the decrease rate of Na⁺ concentration in the test block with added BF is larger than that of the test block without added BF, in which the Na⁺ concentration decreases fastest in the test block with the BF addition amount of 0.1%. With the immersion time of 3 months and 6 months, the Na⁺ concentration at the core part of the test block with the BF content of 0.1% decreased the fastest. However, as the immersion time increased to 9 months, the bridge oxygen bond of the siloxane tetrahedron [14] in the BF reacted with OH⁻, and the bridged oxygen-breaking fibre of the silicon tetrahedron began to peel off, causing the secondary microcracks in the fibre portion of the concrete. This finally resulted in a higher concentration of Na⁺ in the BF-added test block than the BF-free test block.

It can be seen from the apparent crack of the test block and its Na⁺ concentration that the BF addition with 0.1% content can effectively inhibit the concrete cracking propagation and improve the corrosion resistance. This is because the disorderly distributed BF in the concrete effectively suppresses the occurrence of concrete shrinkage cracks and segregation cracks. However, as the erosion time of alkaline solution increased to 9 months, the BF corrosion shedding produced a new Na⁺ migration channel, resulting in that the Na⁺ concentration of BF-added test block is higher than the BF-free test block.

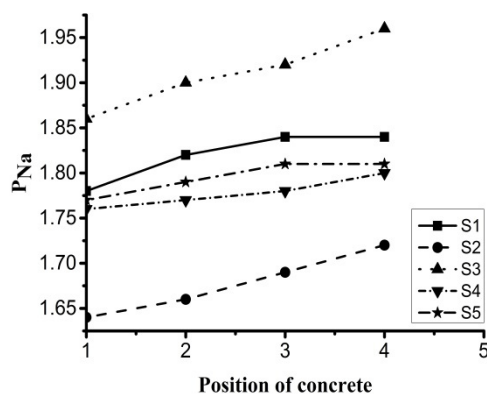


Fig 4. PNa in different position for 3 months

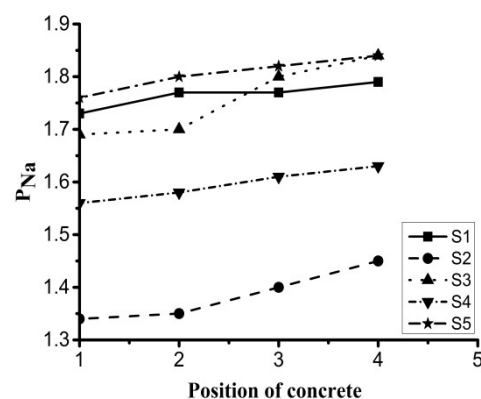


Fig 5. PNa in different position for 6 months

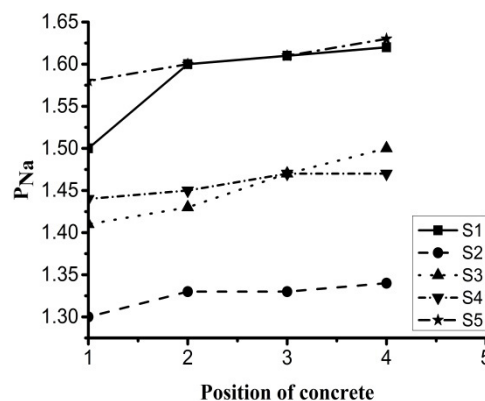


Fig 6. PNa in different position for 9 months

3.2. Analysis of compressive strength

The compressive strength of the test block already immersed for 180d in the 20% NaOH solution was measured to obtain a load-displacement curve as shown in Fig.7. It shows that the BF-added concrete test block has higher ultimate bearing capacity than the test block without added BF. The ultimate bearing capacity of the test block with BF content of 0.1% after immersion for 180 days in NaOH solution is 15% higher than that of the test block without added BF. However, with the BF content of 0.2% and 0.3%, the ultimate bearing capacity of the test block is increased by 11% and 3%, respectively, compared to that of the test block without added BF. From the comparison of experimental data, it is found that the ultimate compressive bearing capacity of concrete is increased most obviously when the added BF content is about 0.1%.

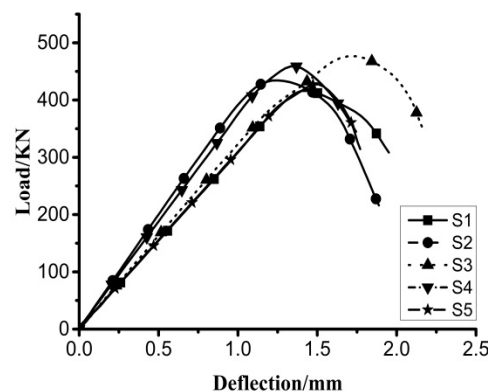


Fig 7. Load-deflection curves of BFRE dip in NaOH solution for 180d

4. Conclusions

The corrosion experiments were conducted for the concrete test blocks with different BF contents in 20% NaOH solution. Finally, it's found that:

- BF can effectively inhibit the generation and propagation of cracks in concrete. The incorporation of appropriate amount of BF can refine the pore structure and reduce the internal defects of the concrete. The incorporation of 0.1% BF significantly improves the alkali resistance of the concrete. However, the excessive addition of BF does not significantly improve the corrosion resistance of concrete.
- The BFRC compression test found that for the concrete test block with 0.1% BF, its bearing capacity increased by 15% than the ordinary concrete under alkaline environment, but the bearing capacity did not increase continuously with the increase of BF content. At the BF content of 0.1%,

it has the most obvious effect on improving the bearing capacity and crack propagation of the test block.

- The addition of BF can significantly inhibit the migration rate of Na⁺ into the concrete and improve the durability of concrete in the short and medium term.

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