Experimental study on performance of fiber concrete under simulated acid rain environment

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Abstract: This experiment studies the influence of different fiber content on the mechanical properties of concrete under simulated acid rain environment (pH=2.5) in the laboratory. Under the action of acid rain erosion, the total content of carbon fiber and basalt fiber are respectively 0.1%, 0.2%, and 0.3%, of which carbon fiber and basalt fiber each account for 50% of the total content. The experiment adopts the cycle immersion method to study the laboratory to simulate acid rain to accelerate the corrosion of concrete. After simulating acid rain corrosion for 25 days, it is naturally dried for 5 days. The compressive strength and splitting tensile strength are measured. The comparison shows that when the total fiber content is 0.2%, the concrete the tensile-compression ratio of the test block is the largest, and its splitting tensile strength increases by 15.09% as the maximum.

1. Introduction

Acid rain refers to atmospheric precipitation with a pH value of less than 5.6. It is a pollution phenomenon caused by the acidification of regional precipitation due to human activities or natural disasters. According to research, since the 1980s, with the rapid development of China's economy, the consumption of oil, coal and other fuels has increased rapidly, which has greatly increased the discharge of acid pollutants in the atmosphere, thereby increasing the distribution of acid rain in China. The degree shows a trend of continuing to expand[1]. The acidic substances in acid rain also have a certain corrosive effect on building materials, and also affect the mechanical properties of concrete, thereby affecting the stability of buildings and reducing the service life of buildings [2]. Therefore, with the continuous expansion of acid rain areas in China, it is very necessary to study the addition of certain additional materials to improve the mechanical properties of concrete under acid rain environments. The additional materials used in this test are carbon fiber and basalt fiber. Different fiber content of mixed carbon fiber-basalt fiber concrete affects the mechanical properties of concrete, so as to find a fiber content that is most conducive to improving the mechanical properties of concrete.

2. Test

2.1. Test materials

This test uses Miaoling brand P.O42.5 cement in Yanbian Korean Autonomous Prefecture, Jilin Province. The fly ash comes from Tienan Heating Company, Yanji City, Jilin Province. The density is 2 200 kg/m3. The particle size of natural coarse aggregate in the test is It is 5-25 mm continuous graded
gravel; the fine aggregate is natural medium sand, and high-fluid self-leveling concrete should be configured, and the sand ratio is 48%. The admixture is a liquid polycarboxylic acid superplasticizer with a solid content of 40%. Carbon fiber and basalt fiber are selected as the additional fiber for the test. The specific fiber parameters are shown in Table 1.

| Fiber specification | Diameter(μm) | Fiber density(kg-m⁻³) | Tensile Strength (MPa) | Tensile modulus of elasticity (GPa) | Elongation of Section |
|---------------------|-------------|-----------------------|------------------------|-----------------------------------|----------------------|
| CF                  | 7.3         | 1.82                  | ≥4000                  | ≥200                              | 2                    |
| BF                  | 17.4        | 2.69                  | ≥2000                  | ≥85                               | 2.5                  |

2.2. Specimen production
The design strength of the concrete in this test is C30, the slump value is 120-150mm, the water-cement ratio is 0.35, the unit water consumption is 185kg/m³, and the fly ash content is 20% of the total weight of the cementitious material. The concrete mix ratio design is shown in Table 2.

| Water | Cement | Fly ash | Sand | Stone | Water-reducing agent |
|-------|--------|---------|------|-------|----------------------|
| 185   | 422.86 | 105.71  | 620.71 | 1012.73 | 5.29                 |

Carbon fiber and basalt fiber are weighed according to the amount in Table 3. Put the mixed fiber, cement powder, coal ash, sand, and stone into a laboratory mixing pot and mix for 1 min to make the fiber uniformly dispersed, and then add water and water reducing agent. Stir. The test block adopts 150mm×150mm×150mm standard test pieces to make compressive and split tensile strength test pieces, a total of 5 groups, each group measures two strengths and 3 test pieces, a total of 30 test pieces. Among them, the first group is a blank control group, no fiber is added, and its 28-day compressive strength is 59.02MPa and the splitting tensile strength is 3.46MPa. The second group is a conditional control group, without fiber, but it should be placed in acid rain environment for 25 days like the other four experimental groups, and then placed naturally for 5 days to dry, and then perform the later strength test. Table 3 shows the specific concrete test block's external fiber dosage.

| Group | Total fiber blending rate (%) | CF blending rate (%) | BF blending rate (%) | CF quality (g) | BF quality (g) |
|-------|------------------------------|----------------------|----------------------|----------------|----------------|
| CG    | 0                            | -                    | -                    | -              | -              |
| CCG   | 0                            | -                    | -                    | -              | -              |
| CBF-1 | 0.1                          | 0.05                 | 0.05                 | 3.67           | 5.21           |
| CBF-2 | 0.2                          | 0.1                  | 0.1                  | 7.33           | 10.33          |
| CBF-3 | 0.3                          | 0.15                 | 0.15                 | 11.0           | 15.63          |

2.3. Experimental method and process
Since the harm of acid rain in China is consistent with the changes in sulfur dioxide emissions in the region, acid rain in China is mainly sulfuric acid rain. In order to accelerate the corrosion of concrete specimens, the laboratory adopts the periodic immersion method. Simulated acid rain accelerates concrete erosion, considering that the acidity of the simulated acid rain solution in the laboratory
affects the corrosion rate of the concrete test block, so the simulated acid rain environment adopts
sulfuric acid rain with a pH of 2.5, and the laboratory uses HNO₃ to adjust the pH to accelerate Corrosion
[5], the laboratory simulated acid rain corrosion of concrete test block is shown in Figure 1.

The four groups of CCG, CBF-1, CBF-2, and CBF-3 were immersed in a simulated acid rain solution
in the laboratory for 25 days, and the test was carried out at room temperature and normal pressure.
During the soaking period, because the acidic substance in the solution will react with the concrete
[6,7], the pH of the simulated acid rain solution changes slightly during the test. In order to maintain the pH
of the solution constant during the test, the acidity of the solution is measured with a pH meter every
day. HNO₃ to adjust the pH. Do not control the external environment of the test block during the soaking
process, just place it in the laboratory normally. After the test block is soaked for 25 days, take out the
test block and observe the thin layer of loose powder on the surface of the test block, which is obviously
corroded, as shown in Figure 2. Place the test block in a natural laboratory environment to dry for 5
days, and measure its compressive strength and split tensile strength after drying.

Figure 1.Simulated acid rain solution corrosion test block. Figure 2. A thin layer of loose powder on the surface.

3.Test results and analysis

3.1. Test results

Use a laboratory universal machine to determine the compressive strength and split tensile strength of
concrete specimens treated in a simulated acid rain environment (Note: CG group has not been treated
with laboratory simulated acid rain solution. The table shows that after 28 days of curing in the curing
chamber. Measure its compressive strength and split tensile strength. The strengths of CCG, CBF-1,
CBF-2, and CBF-3 in the table are the strengths of the test block after 25 days of simulated acid rain
treatment and 5 days of natural drying), The concrete failure form is shown in the Figure 3 and Figure4,
and the test results are shown in Table 4.

Figure 3.Compression test of specimen. Figure 4.Specimen splitting tensile test.

| Group | Compressive strength (MPa) | Compressive strength increase rate (%) | Splitting tensile strength (MPa) | Splitting tensile strength increase rate (%) | Tension and compression ratio |
|-------|---------------------------|---------------------------------------|-------------------------------|-------------------------------------------|-------------------------------|
| CG    | 59.02                     | -                                     | 3.46                          | -                                         | 0.059                         |
| CCG   | 69.58                     | -                                     | 5.91                          | -                                         | 0.085                         |
3.2. Analysis of test results

Comparing the compressive strength and splitting compressive strength of CG and CCG, it can be found that the compressive strength and splitting tensile strength of the concrete test block after the laboratory simulated acid rain solution treatment have increased, which is compared with other simulated acid rain environments. The conclusions drawn from the experimental research on the mechanical properties of concrete are consistent with [4]. After 25 days of simulated acid rain corrosion in the laboratory at pH=2.5, the compressive strength and splitting tensile strength of the specimens have increased.

|       | CBF-1 | CBF-2 | CBF-3 |
|-------|-------|-------|-------|
|       | 62.10 | 65.26 | 66.16 |
| Increase rate: CBF group relative to CCG group. |

From Figure 5, in the laboratory simulated acid rain environment, adding carbon fiber and basalt fiber will reduce the compressive strength of concrete. When the total fiber content is 0.1%, the compressive strength of the concrete block will be reduced to the minimum that 62.10MPa, then with the increase of the total fiber content, the compressive strength relative to the reduction rate of CCG decreased. The tensile-compression ratio of the experimental group has increased relative to that of CCG. As a brittle material, concrete has the disadvantages of low tensile strength and weak crack resistance. The test data shows that in the laboratory simulated acid rain environment, adding carbon fiber and basalt fiber to concrete can effectively increase the splitting tensile strength, thereby increasing the toughness. It can be seen from Figure 6 that under the simulated acid rain environment in the laboratory, adding proper amount of basalt fiber and carbon fiber will increase the splitting tensile strength of the concrete block. With the increase of fiber content, the splitting resistance of the concrete block the compressive strength increases first and then decreases. When the fiber content is 0.2%, the maximum split compressive strength is 6.96 MPa.

3.3. Test conclusion

3.3.1 In a laboratory simulated acid rain environment, adding carbon fiber and basalt fiber can effectively improve the splitting tensile performance of concrete, thereby increasing the toughness of concrete. The splitting tensile strength of concrete increases first and then decreases with the increase of fiber content, so the fiber content should not be too large. When the fiber content is 0.2%, the splitting tensile strength is the largest, that is, the mixed fiber pair The splitting tensile strength of concrete improves most obviously.

3.3.2 In a laboratory simulated acid rain environment, adding carbon fiber and basalt fiber will reduce the compressive strength of concrete, and the compressive strength relative to the CCG reduction rate is
negatively related to the fiber blending rate. When the total blending rate of carbon fiber and basalt fiber is 0.3%, the compressive strength reduction rate is at least 5.17%.

3.3.3 When the optimal blending rate of this test is 0.2% of the total fiber blending rate, the tensile-compression ratio of the concrete test block is the largest, and its splitting tensile strength increases by 15.09% as the maximum.

4. Conclusion
The development of China has always been adhering to the principle of sustainable development. The process of industrialization is accelerating and the expansion of acid rain areas will affect the service life of industrial buildings and civil buildings. This test shows that in an acid rain corroded environment, evenly mixing carbon fiber and basalt fiber into concrete can effectively improve the comprehensive mechanical properties of concrete, and can effectively increase the tensile strength of concrete, thereby improving the toughness of concrete. When the total fiber blending rate is 0.2%, the overall effect is the best. Carbon fiber-basalt fiber concrete can prolong the service life of buildings under acid rain environment and can be used in the actual production process.

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