Study on the Weakening Performance of Fiber Concrete under the Action of Acid Rain-sewage Coupling Erosion

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Abstract. Unfavorable environments such as acid rain corrosion and sewage erosion will have a great impact on the mechanical properties and durability of concrete structures. In order to further explore the weakening performance of concrete structures in harsh environments such as acid rain and sewage, plain concrete, basalt concrete with 0.08%, 0.1%, and 0.12% fiber content were adopted for comparative analysis. The weakening of compressive and flexural strength of concrete with different fiber content under sewage erosion and acid rain corrosion were investigated. The results of this paper can provide reference value for further research on the deterioration performance and life prediction of structures under long service life.

1. Introduction

In recent years, with the development of industrial technology, various environmental problems have become increasingly prominent. Rainwater acidification, industrial sewage and other phenomena emerge in an endless stream. Such environmental deterioration will not only affect the natural environment such as lakes and mountains, but also have a certain impact on non-metallic materials such as concrete[1-2]. Many scholars at home and abroad have conducted many studies[3] on the damage effect of ordinary concrete structure under harsh environment. However, the influence of steel fiber, polypropylene fiber, basalt fiber and other external fibers on concrete performance degradation is not in-depth enough at present, and further analysis and research are needed.

2. Cause Analysis of Erosion

2.1. Acid Rain Corrosion

With the extensive use of fossil fuels in human activities, the acidification of rainwater has become more severe. Relevant statistical data show that[4], by the beginning of this century, acid rain has become one of the important problems affecting agriculture, construction, environment and other industries. As for the fiber concrete structure in the construction field, the long-term erosion of acid rain will not only cause cracks, carbonization and other damages on the surface of the concrete, but also chemically react with the Ca2+ ions in it to produce ettringite products, which will damage the fiber bonds. As a result, the internal micro-cracks expand and the structure is damaged.

The corrosion mechanism of fiber concrete under the action of acid rain can be divided into two stages[5]: the destruction of surface concrete in the first stage is basically equal to that of ordinary concrete, mainly due to the erosion of surface concrete by H+ and SO42- ions in acid rain solution, resulting in cracking and surface corrosion. In the second stage, the internal structure is destroyed mainly by the aggravation of cracking, the expansion thrust of ettringite and the destruction of fiber bonds.
bond caused by acid corrosion. These corrosion actions tend to weaken the durability and mechanical properties of concrete structure.

2.2. Sewage Erosion
The composition of sewage is quite complex, including not only inorganic compounds such as nitrogen and phosphorus elements, various acids and salts, but also organic compounds such as urea and protein. According to its formation, sewage can generally be divided into two categories: domestic sewage and industrial wastewater. On the one hand, concrete sewage pipes and various water treatment culvert structures will be subject to serious corrosion if they are in direct contact with sewage of various compositions for a long time. On the other hand, concrete drainage culverts in mines and chemical enterprises are also affected by all kinds of industrial wastewater for a long time, which also has a great impact on their durability life[6-7].

2.3. Acid Rain-Sewage Coupling Effect
With the intensification of urbanization and industrial development, the discharge of various types of waste gas and waste water will not only cause natural environmental hazards such as acid rain, but also cause a large amount of industrial pollution. The deterioration of the natural environment and the impact of human activities often have a certain degree of intersection. For example, various concrete structures directly damaged by acid rain washing and sewage soaking for a long time will cause great damage to the structure; therefore, it is particularly important to study the coupling effect of acid rain erosion and sewage soaking. A large number of studies have shown that the addition of fiber can further optimize the properties of concrete materials in terms of mechanical properties, permeability, carbonization and so on. Therefore, based on the common erosion environment of acid rain-sewage, it is of practical significance to carry out comparative study and analysis on the content and types of fiber, such as steel fiber, polypropylene fiber, basalt fiber and other kinds of admixture fibers, as well as research from the aspect of corrosion resistance.

3. Analysis of Mechanical Indexes under Acid Rain-Sewage Erosion[8]

3.1. Compressive Strength Analysis
Under the action of acid rain washing and sewage soaking, the stability of the internal structure of concrete will gradually decrease, resulting in the deterioration of its mechanical performance. Taking basalt fiber concrete as an example, its compressive strength under the action of acid rain and sewage erosion was investigated. The concrete with basalt fiber content of 0%, 0.08%, 0.10%, and 0.12% was selected as the object, and the sewage erosion environment was simulated by sewage immersion, and the acid rain corrosion environment was simulated by the dry and wet cycle, and the compressive strength of different ages was obtained as shown in Figure 1.
It can be seen from Figure 1(a) that the compressive strength of concrete with different fiber content in the clear water environment presented an increasing trend, which is due to the fact that the clear water environment is conducive to its hydration and contributes to its strength improvement to a certain extent. From the changes of the compressive strength in Figure 1(b) and (c), it can be seen that the compressive strength of fiber concrete generally showed a downward trend under the action of sewage erosion or acid rain corrosion. This phenomenon indicates that the long-term erosion of sewage and the continuous corrosion of acid rain would reduce the mechanical properties of fiber concrete structures, especially had a quite prominent impact on the weakening of compressive. From the perspective of fiber content, the influence of different fiber content on the reduction of compressive strength had certain differences. In order to further study the effect of fiber content on clean water environment, sewage erosion and acid rain corrosion, the relevant data in Figure 1 was fitted and analyzed to obtain the change of the compressive strength over time as shown in Table 1.

Table 1. Comparison of fitting relationship between different environments and compressive strength at 0~180d age

| Fiber volume ratio/% | Environment       | 0~180d age          | Fitness $R^2$/% | Slope K |
|---------------------|-------------------|---------------------|----------------|---------|
| 0                   | Clean water       | $f_{cu} = 0.01345T + 37.75$ | 0.8741         | 0.01345 |
| 0.08                |                   | $f_{cu} = 0.02T + 40.69$   | 0.8898         | 0.02    |
| 0.1                 |                   | $f_{cu} = 0.01583T + 42.5$ | 0.7654         | 0.01583 |
| 0.12                |                   | $f_{cu} = 0.01512T + 41.2$ | 0.7503         | 0.01512 |
| 0                   | Sewage erosion    | $f_{cu} = -0.055T + 37.42$ | 0.8997         | -0.055  |
| 0.08                |                   | $f_{cu} = -0.029T + 40.43$ | 0.8177         | -0.029  |
| 0.1                 |                   | $f_{cu} = -0.03T + 41.27$  | 0.9283         | -0.03   |
| 0.12                |                   | $f_{cu} = -0.035T + 39.68$ | 0.9175         | -0.035  |
| 0                   | Acid-rain corrosion| $f_{cu} = -0.079T + 35.58$ | 0.952          | -0.079  |
| 0.08                |                   | $f_{cu} = -0.06T + 38.3$   | 0.882          | -0.06   |
| 0.1                 |                   | $f_{cu} = -0.054T + 38.93$ | 0.7926         | -0.054  |
| 0.12                |                   | $f_{cu} = -0.06T + 38.37$  | 0.9058         | -0.06   |

fcu is the compressive strength of fiber concrete (MPa).

Table 1 shows the comparison of fitting relation between compressive strength and time in clean water, sewage erosion and acid rain corrosion environment. Through the comparison of slope K, it can be seen that the difference of external environment had a certain influence on the compressive strength of concrete materials. The slope $K>0$ in the clean water environment indicates that the compressive strength had a certain degree of enhancement, while in the sewage erosion and acid rain corrosion environment, the slope $K<0$ indicates that the compressive strength had a certain degree of degradation. And through the difference between the slope K values, it can be seen that for different fiber volume ratios, there are also certain differences in the deterioration degree and rate of the compressive strength over time. With the increase of fiber content, the compressive strength basically decreased first and then increased. Compared with sewage erosion environment, acid rain corrosion environment had stronger weakening performance to its compressive strength. For the sewage corrosion environment, when the fiber volume ratio was 0.08%, its corrosion resistance was the best; for the acid rain corrosion environment, when the fiber volume ratio was 0.1%, its corrosion resistance was the best. The constant term in the fitting relationship between compressive strength and age reflected the improvement effect of its compressive strength, and apparently the compressive strength was improved most obviously when the fiber content was 0.1%.
3.2. Flexural Strength Analysis

Sewage erosion and acid rain corrosion also have a certain impact on the internal flexural performance of concrete structures. The test data of fiber concrete were further analyzed to explore the correlation between the flexural strength and corrosion age of concrete with different fiber content. The change of the flexural strength of fiber concrete at the age of 0d–180d is shown in Figure 2.

![Image](a) clean water  (b) sewage erosion  (c) acid-rain corrosion

Figure 2. Relationship between flexural strength and age under different environmental influences

It can be seen from Figure 2(a) that the concrete flexural strength with different fiber content in the clean water environment had little change and basically presented an upward trend. This is because the clean water curing has a certain positive influence on the hydration of concrete and can improve its flexural strength to a certain extent. From the changes in the flexural strength shown in Figure 2(b) and (c), it can be seen that the flexural strength of fiber concrete generally showed a downward trend under sewage erosion or acid rain corrosion. This phenomenon indicates that the long-term erosion of sewage and the continuous corrosion of acid rain will reduce the mechanical properties of fiber reinforced concrete structure, and also have a great impact on the deterioration of its flexural strength. From the perspective of fiber content, the influence of different fiber content on the deterioration of flexural strength had certain differences. In order to further study the effect of the fiber content on the sewage corrosion environment and the acid rain corrosion environment, the relevant data in Figure 2 was fitted and analyzed to obtain the change of the flexural strength over time as shown in Table 2.

| Fiber volume ratio% | Environment       | 0~180d age        | Fitness R²/% | Slope K  |
|---------------------|-------------------|-------------------|--------------|----------|
| 0                   | Clean water       | $f_{cm} = 0.00368T + 6.722$ | 0.8727       | 0.00368  |
| 0.08                |                   | $f_{cm} = 0.00607T + 7.099$ | 0.9084       | 0.00607  |
| 0.1                 |                   | $f_{cm} = 0.00376T + 7.556$ | 0.9273       | 0.00376  |
| 0.12                |                   | $f_{cm} = 0.00475T + 7.617$ | 0.9273       | 0.00475  |
| 0                   | Sewage erosion    | $f_{cm} = -0.00727T + 6.663$ | 0.9845       | -0.00727 |
| 0.08                |                   | $f_{cm} = -0.00455T + 6.989$ | 0.9915       | -0.00455 |
| 0.1                 |                   | $f_{cm} = -0.00539T + 7.487$ | 0.9683       | -0.00539 |
| 0.12                |                   | $f_{cm} = -0.00568T + 7.743$ | 0.988        | -0.00658 |
| 0                   | Acid-rain corrosion| $f_{cm} = -0.01312T + 6.696$ | 0.9984       | -0.01312 |
| 0.08                |                   | $f_{cm} = -0.01027T + 6.992$ | 0.998        | -0.01207 |
| 0.1                 |                   | $f_{cm} = -0.01157T + 7.503$ | 0.9954       | -0.01157 |
| 0.12                |                   | $f_{cm} = -0.01264T + 7.514$ | 0.9962       | -0.01264 |

$f_{cm}$ is the flexural strength of fiber concrete (MPa).

Table 2 shows the comparison of fitting relation between flexural strength and time in clean water, sewage erosion and acid rain corrosion environment. Through the comparison of slope K, it can be
seen that the difference of external environment had a certain influence on the flexural strength of concrete materials. The slope $K>0$ under clean water indicates that this environment had certain enhancement effect on its flexural strength, while under the environment of sewage erosion and acid rain corrosion, the slope $K<0$ indicates that the influence of these environmental conditions had a certain deterioration effect on its flexural strength. And through the difference between the slope $K$ values, it can be seen that for different fiber volume ratios, there were also certain differences in the degree and rate of degradation of the flexural strength over time. With the increase of fiber content, the flexural strength basically decreased first and then increased. And compared to the sewage corrosion environment, the acid rain corrosion environment has stronger weakening performance to its flexural strength. When the fiber content was 0.1%, its resistance to sewage erosion and acid rain corrosion was the strongest, and the improvement effect of flexural strength was also the best.

4. Conclusion
In this paper, by studying the strength degradation of fiber concrete under the action of sewage erosion and acid rain corrosion, the following conclusions are obtained:

1. Sewage erosion, acid rain corrosion and other adverse environments would weaken the mechanical properties of fiber concrete. Compared with the flexural strength, the compressive strength weakens more obviously.

2. Acid rain corrosion had a more obvious effect on the deterioration of fiber concrete's compressive performance than sewage erosion. For the compressive strength, when the fiber content was 0.8%, its resistance to sewage erosion was the strongest, and when the fiber content was 1%, its acid rain corrosion resistance was the best.

3. The impact of sewage erosion on the flexural property of fiber concrete was more obvious than acid rain corrosion. Regarding the flexural strength, when the fiber content was 1%, its resistance to sewage erosion and acid rain corrosion reached the best, and the flexural strength improved better.

4. The compressive and flexural equations obtained from the research on the degradation performance of fiber concrete under sewage erosion and acid rain corrosion environments can provide reference value for further research on the degradation performance and life prediction of structures under long-term service life.

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