Experimental Study on Carbonation Behavior of Waste Fiber Recycled Concrete

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Abstract: Based on the rapid carbonization test process of concrete, this paper studies and analyzes the influence of water-cement ratio, recycled aggregate content, fiber length and fiber content on the carbonation rule change of waste fiber recycled concrete. The results show that the depth of carbonization increases with the increase of water-cement ratio. With the increase of the replacement rate of recycled aggregate, the carbonation depth increases. The carbonation depth decreases with the increase of fiber length. As the proportion of waste fiber content increases, the carbonation depth does not change monotonously. The best content is 0.12%.

1. Introduction
With the deepening of China's reform and opening up, the contradiction among resources, environment and population is escalating. Therefore, in this context, while ensuring the sustainable development of China's economy, we must consider the rational allocation of resources and sustainable development. A new green building material that can make use of both waste fiber and waste concrete, waste fiber recycled concrete, plays an important role in sustainable green development and has become a hot topic worldwide [1].

Compared with ordinary concrete, recycled concrete has some disadvantages, such as low strength, poor ductility. Adding appropriate fiber recycled concrete, not only can effectively improve the performance of recycled concrete, but also can realize recycling, waste, to protect the natural environment and maintaining ecological balance [2].

Before large-scale use of waste fiber recycled concrete, necessary research should be conducted on its durability. As one of the important indexes to measure the durability is carbonization depth. Based on the rapid carbonization test, the influences of water cement ratio, recycled aggregate content, waste fiber length, and waste fiber content were studied respectively.

2. Experiment Overview

2.1 Materials
Cement use P.O 42.5R ordinary Portland cement; fine aggregate comes from high quality river sand and selected from middle sand in the secondary distribution area; natural coarse aggregate selection of hard texture, good gradation of gravel, more use of relatively uniform side length polyhedron; Recycled coarse aggregate was taken from the laboratory, with the initial strength of C40. After crushing, cleaning, screening and other steps, the recycled coarse aggregate with the particle size range of 5~25mm; waste fibers are made of polypropylene (pp), which is manually removed and cut as waste fibers for testing. The lengths are 12mm, 19mm and 30mm; tap water is used for water.
2.2 Design of proportioning ratio

In the process of deploying recycled concrete with waste fiber, the water used for waste fiber does not need to be considered, because the waste fiber does not absorb water [3]. Based on the proportioning ratio design of free water-cement ratio, the water consumption in this test can be divided into two parts: one is the free water consumption calculated according to the proportioning ratio design method of ordinary concrete (that is, the water consumption involved in hydration); the other part is considering the difference of water absorption rate between recycled concrete and natural aggregate, and the additional consideration of adsorbed water. In conclusion, the proportioning ratio design based on free water-cement ratio is shown in Table 1 below.

| Water cement ratio | Recycled coarse aggregate content (%) | Cement (kg) | Sand (kg) | Gravel (kg) | Regenerate coarse aggregate (kg) | Free water (kg) | Adsorbed water (kg) |
|-------------------|--------------------------------------|-------------|-----------|-------------|---------------------------------|----------------|--------------------|
| 0.45              | 50%                                  | 433         | 674       | 1148        | 0                               | 195            | 0                  |
|                   | 100%                                 | 433         | 674       | 0           | 1148                            | 195            | 20                 |
| 0.5               | 50%                                  | 390         | 709       | 1156        | 0                               | 195            | 0                  |
|                   | 100%                                 | 390         | 709       | 0           | 1156                            | 195            | 20                 |
| 0.55              | 50%                                  | 355         | 741       | 1159        | 0                               | 195            | 10                 |
|                   | 100%                                 | 355         | 741       | 0           | 1159                            | 195            | 20                 |

2.3 Experiment Plan

This test mainly studies the water cement ratio, recycled aggregate content, waste fiber length, waste fiber content, carbonation age, pouring surface difference and Angle zone effect on concrete carbonation performance. Therefore, on the basis of the above proportioning ratio design of waste fiber recycled concrete, the test scheme shown in Table 2 is designed [4].

| Test Number | Water Cement Ratio | Recycled Aggregate Content (%) | Length of Fiber /mm | Content of Fiber (%) | Quantity of specimen |
|-------------|--------------------|--------------------------------|---------------------|----------------------|----------------------|
| A1          | 0.45               |                                |                     |                      | 3                    |
| A2          | 0.5                | 50                             | 19                  | 0.08                 | 3                    |
| A3          | 0.55               |                                |                     |                      | 3                    |
| B1          | 0.5                | 0                              | 19                  | 0.08                 | 3                    |
| B2          | 0.5                | 100                            | 12                  | 0.08                 | 3                    |
| C1          | 0.5                | 50                             | 30                  | 0.08                 | 3                    |
| C2          | 0.5                |                                | 0                   |                      | 3                    |
| D1          | 0.5                | 50                             | 19                  | 0.12                 | 3                    |
| D2          | 0.5                |                                | 0                   |                      | 3                    |
| D3          | 0.5                |                                | 0                   |                      | 3                    |
| E1          | 0.5                | 0                              | 0                   |                      | 3                    |
3. Experiment Equipment and Method
This experiment adopts concrete carbonization test box, in this experiment we study the influence of different variables on carbonization performance of waste fiber recycled concrete. The water-cement ratio are 0.45, 0.50 and 0.55; the content of recycled aggregate are 0, 50% and 100%; the lengths of waste fiber are 12mm, 19mm and 30mm; the content of waste fiber was 0, 0.08%, 0.12% and 0.16%; Carbonation ages are 3d, 7d, 14d and 28d; pouring surface takes top, bottom, right and left side; corner takes the left and the right corner. The size of the specimen is a prism of 100mm×100mm×400mm., and each scheme make three specimens[5][6].

Carbonization steps are carried out according to GBT50082-2009 "Standard for Test Methods of Long-term Performance and Durability of Ordinary Concrete."

4. Experiment Results and Data Analysis

4.1 Influence of water-cement ratio
Experimental group A mainly studied the influence of water-cement ratio on carbonation depth of waste fiber recycled concrete. The water-cement ratio are 0.45, 0.50 and 0.55. The relation curve between carbonization depth and water-cement ratio is shown in figure 1.

![Figure 1. Carbonation Depth of Waste Fiber Recycled Concrete under Different Water-cement Ratio](image)

According to the figure, with the increase of water-cement ratio, the carbonization depth of waste fiber recycled concrete also increases correspondingly. The reason is that with the increase of water-cement ratio, the water consumption in concrete will increase. Therefore, the porosity of concrete will also increase, and the carbonization reaction process will be accelerated.

4.2 Influence of Recycled Aggregate Content
Experimental groups B and A2 mainly studied the influence of recycled aggregate content on carbonization depth of waste fiber recycled concrete. The content of recycled aggregate are 0, 50% and 100%, and the relation curve of carbonation depth and recycled aggregate content was shown in figure 2.
Figure 2. Carbonation Depth of Waste Fiber Recycled Concrete under Different Content of Recycled Aggregate

It can be seen from the figure that the higher the replacement rate of recycled aggregate is, the greater the carbonization depth of waste fiber recycled concrete is. This is because there is a large amount of cement mortar attached to the surface of recycled aggregate, which will generate pores at the interface of newly generated mortar, thereby increasing the porosity of recycled concrete with overall waste fiber. At the same time, new cracks and pores will be generated in the crushing process of recycled aggregate, which will reduce the compactness of waste fiber recycled concrete and increase the carbonization depth.

4.3 Influence of Fiber Length
Experimental groups C and A2 studied the influence of fiber length on carbonization depth of waste fiber recycled concrete. The fiber length is 12mm, 19mm and 30mm respectively. The specific relation curve between carbonization depth and fiber length is shown in figure 3.

Figure 3. Carbonation Depth of Waste Fiber Recycled Concrete under Different Length of Fiber

It can be seen from the figure that the longer the fiber length is, the lower the carbonization depth of waste fiber recycled concrete is. This is because the addition of waste fiber can alleviate the cracking and shrinkage of waste fiber recycled concrete to a certain extent and reduce the overall internal porosity. On the premise of maintaining the same fiber content, with the increase of fiber length, the crack resistance of waste fiber recycled concrete is also improved, resulting in the increase of carbonization resistance of waste fiber recycled concrete.
4.4 Influence of Fiber Content
Experimental groups D and A2 studied the influence of different fiber content on carbonization properties of waste fiber recycled concrete. Fiber content is 0, 0.08%, 0.12% and 0.16%. The relationship curve between carbonization depth and fiber content is shown in figure 4.

According to the figure, when the waste fiber content is less than 0.12%, the carbonization depth decreases with the increase of the waste fiber content. When the fiber content is more than 0.12%, the carbonization depth increases with the increase of waste fiber content. This is because when the appropriate amount of fiber is added, the fiber is evenly dispersed in the concrete, so that the overall formation of uniform composite products, play the role of optimizing pores; On the contrary, the uneven fiber dispersion caused by excessive dosage cannot achieve the ideal effect of uniform distribution, which leads to the occurrence of weak spots inside concrete, among which the weak spots are most likely to produce cracks and large pores, which is extremely unfavourable to the carbonization resistance of concrete[7].

5. Conclusion
This chapter studies the influence of water-cement ratio, recycled aggregate content, fiber length and fiber content on the carbonization depth of waste fiber recycled concrete through rapid carbonization test, and comes to the following conclusions:
- The greater the water-cement ratio, the greater the carbonization depth of waste fiber recycled concrete;
- The higher the replacement rate of recycled aggregate, the greater the carbonization depth of waste fiber recycled concrete;
- The longer the fiber length is, the smaller the carbonization depth of waste fiber recycled concrete is;
- With the increase of proportion of waste fiber content, carbonization depth does not change monotonously, and when the content is 0.12%, it is the optimal content in the test.

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