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# Effects of Waste Hybrid Fibers with Different Mixing Ratios on Properties of Recycled Concrete

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# Effects of Waste Hybrid Fibers with Different Mixing Ratios on Properties of Recycled Concrete

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**Abstract**. In order to improve the performance and application scope of recycled concrete and reduce environmental pollution, fly ash and recycled coarse aggregate of waste concrete were used to replace part of cement and part of natural coarse aggregate respectively, and recycled concrete of base group was mixed. The mixing amount of waste polypropylene fibers and basalt fibers was changed in recycled concrete of base group, and its fluidity and mechanical properties were analyzed. The experimental results show that the mixed fibers have little effect on the fluidity of recycled concrete, but the compressive strength, flexural strength and elastic modulus all decrease. However, they can enhance the splitting tensile strength of recycled concrete, and the strengthening effect is more obvious with the increase of the blending ratio of waste polypropylene fibers.

## 1. Introduction

With the development of textile industry, China's textile consumption has increased rapidly, and textile waste has also increased year by year. Some data show that the main components of textiles are non-degradable polypropylene, polyester and so on. Landfill or incineration is the usual treatment method[1] for this kind of waste, which not only seriously pollutes the environment, but also wastes a lot of land resources. The research data show that polypropylene fibers have the characteristics of high tensile strength, high ultimate elongation, low elastic modulus and strong alkali resistance. It can be processed into recycled fibers and applied to recycled concrete to reduce the occurrence and development of primary cracks in early concrete[2-3], and improve the defects of recycled concrete such as easy cracking and low tensile strength[4-6]. For example, the test of Zhou Jinghai [7] proved that the splitting tensile strength and compressive strength of recycled concrete with waste polypropylene fibers are improved compared with recycled concrete without fibers. the experiments of Li Yanfei [8] proved that the compressive strength, splitting tensile strength, flexural strength and crack suppression of concrete with polypropylene fiber reinforced concrete are improved compared with ordinary concrete, and the strength of hybrid fiber reinforced concrete is more obvious than that of single fiber reinforced concrete. the test of Zhao Bingbing [9] proved that the compressive strength of matrix concrete can be reduced by adding fibers into concrete; the splitting tensile strength and flexural strength of matrix can be improved by adding fibers with low content; and the failure mode of concrete can be greatly improved, in which the mixing of basalt fibers and polypropylene fibers is better than that of single-doped fibers.

In order to improve the reutilization rate of recycled resources, this study changes the mixing ratio of waste polypropylene fibers and basalt fibers in recycled concrete, studies the fluidity and basic mechanical properties of recycled concrete, and provides technical reference for expanding the utilization of recycled resources.

## 2. Design and method of test scheme

### *2.1. Design of test scheme*

The design strength of concrete in this experiment is C30, the water-cement ratio is 0.35, the fly ash of 20% (the percentage of total gel mass) is used to replace part of cement, the recycled aggregate of 30% (the percentage of total coarse aggregate mass) is used to replace natural aggregate[10], the sand ratio is 0.45, the water reducer ratio is 1% (the percentage of total cementitious mass), and the total blending ratio of hybrid fibers is controlled at a level of 0.3%. Five groups of experiment groups are designed by changing the mixing ratio of waste polypropylene fibers and basalt fibers. The slump and expansion of concrete are measured under plastic state after mixing, and the 28-day compressive strength, splitting tensile strength, elastic modulus and flexural strength of concrete are measured under hardening state. The mix proportion used in this experiment is shown in table 1.

Table 1. Mix proportion of recycled concrete(kg/m$^3$).

| Test group | Water | Cement | Fly ash | Fine aggregate | Natural coarse aggregate | Recycled coarse aggregate | Waste polypropylene fibers | Basalt fibers | Water reducer |
|---|---|---|---|---|---|---|---|---|---|
| $P_0B_{100}$ | 178 | 356 | 89 | 813.57 | 561.55 | 244.07 | 0 | 6.90 | 2.23 |
| $P_{25}B_{75}$ | 178 | 356 | 89 | 813.57 | 561.55 | 244.07 | 0.68 | 5.18 | 2.23 |
| $P_{50}B_{50}$ | 178 | 356 | 89 | 813.57 | 561.55 | 244.07 | 1.37 | 3.45 | 2.23 |
| $P_{75}B_{25}$ | 178 | 356 | 89 | 813.57 | 561.55 | 244.07 | 2.05 | 1.73 | 2.23 |
| $P_{100}B_0$ | 178 | 356 | 89 | 813.57 | 561.55 | 244.07 | 2.73 | 0 | 2.23 |

Note: $P_XB_Y$: P is waste polypropylene fibers and B is basalt fibers in the test number. The subscript values X and Y are the relative percentage of waste polypropylene fibers and basalt fibers, respectively. When the values X and Y are 0, this kind of fiber is not added.

### *2.2. Test raw materials*

The cement used in this test is P.O 42.5 ordinary Portland cement produced by a factory in Korean Autonomous Prefecture of Yanbian, with a density of 3150 kg/m$^3$, and fly ash produced by a power plant in Yanji City with a density of 2180 kg/m$^3$. The fine aggregate originated from natural yellow sand in Yanji City is medium sand with good gradation and density of 2610 kg/m$^3$. The recycled coarse aggregate is crushed by jaw crusher from waste concrete in laboratory, with particle size of 5-25 mm, apparent density of 2550 kg/m$^3$ and water absorption rate of 1.5%. The natural coarse aggregate has particle size of 5~25 mm and apparent density of 2650 kg/m$^3$. The superplasticizer used in this experiment is light yellow liquid polycarboxylic acid superplasticizer with solid content of 20%. Waste polypropylene fibers are used carpets which are cut and processed by ourselves in the laboratory. The length of the fibers is 6 mm and that of basalt fibers are 18 mm. The physical properties of waste polypropylene fibers and basalt fibers are shown in table 2.

Table 2. Physical properties of waste polypropylene fibers and basalt fibers.

| Category | Modulus of elasticity (GPa) | Length(mm) | Density(kg/m3) | Limit elongation(%) |
|---|---|---|---|---|
| Waste polypro-pylene fibers | 93.1～110 | 6 | 2.30 | 3.1 |
| Basalt fibers | 3～9 | 18 | 0.91 | 15～20 |

### *2.3. Test method*

The specimens were made according to *Standards for Testing Methods of Mechanical Properties of Ordinary Concrete*(GB/T 50081-2002). The size of compressive strength specimens is 150 mm × 150 mm × 150 mm; the size of splitting tensile specimens is 150 mm × 150 mm × 150 mm; the size of flexural strength specimens is 150 mm × 150 mm × 550 mm; and the size of elastic modulus specimens is 150 mm × 150 mm × 300 mm. In order to ensure the uniformity of concrete mixtures, dry mixing method is adopted in this experiment. First, aggregate, cement and fly ash are added, after mixing evenly, waste polypropylene fibers and basalt fibers are added and stirred for 30 seconds. After fully dispersing the fibers, water and water reducer are added to mix 180 seconds. According to *Slump Detection of Concrete* (GD2301034), the slump and expansion of concrete under plastic state are measured, and then the mould is loaded and vibrated, and the maintenance room is maintained for 24 hours to demould. Continue to maintain under standard conditions until 28 days. The cubic compressive strength, flexural strength, splitting tensile strength and elastic modulus of each experiment group were measured according to the method prescribed in *Standard for Testing Mechanical Properties of Ordinary Concrete*(GB/T50081).

## 3. Test results and analysis

### *3.1. Slump*
Figure 1 shows the slump of hybrid fiber recycled concrete with different mixing ratio. It can be seen from the figure that the slump of concrete changes slightly with the change of the mixing ratio of hybrid fibers, but it does not change much. The slump of $P_{50}B_{50}$ group reaches the maximum value, which is 224mm. This shows that the change of hybrid fibers content ratio has little effect on the fluidity of recycled concrete.

### *3.2. Compressive strength*
Figure 2 shows the 28-day compressive strength of hybrid fiber recycled concrete with different mixing ratios. It can be seen from the figure that when waste polypropylene fibers and basalt fibers are mixed, the compressive strength increases obviously with the increase of basalt fibers. The compressive strength of recycled concrete with basalt fibers is the highest, which is 36.58 MPa. Secondly, the highest compressive strength was 30.90 MPa in waste polypropylene fibers group. This shows that the reinforcing effect of single-doped fiber is better than that of mixing fibers.

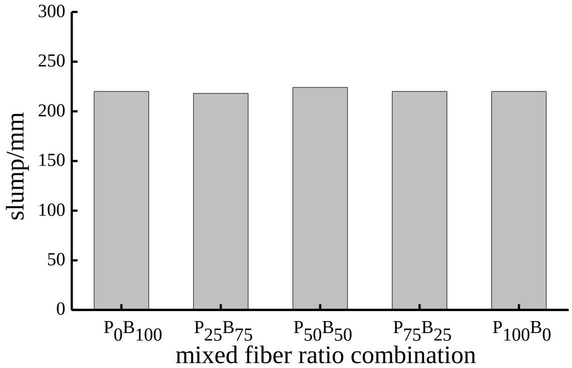


Figure 1. Slump of hybrid fiber recycled concrete with different mixing ratios.

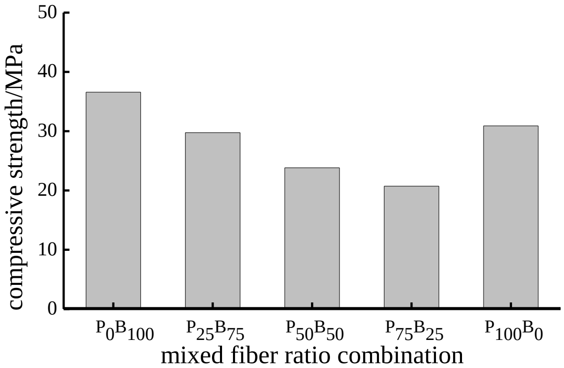


Figure 2. Compressive strength of hybrid fiber recycled concrete with different mixing ratios.

### *3.3. Flexural strength*
Figure 3 shows the 28-day flexural strength of hybrid fiber recycled concrete with different mixing ratios. It can be seen from the figure that the flexural strength of recycled concrete with basalt fibers is the highest, which is 2.88 MPa. When basalt fibers and waste polypropylene fibers are mixed, the flexural strength of recycled concrete decreases with the increase of waste polypropylene fibers dosage, and the lowest flexural strength of $P_{75}B_{25}$ group is 2.29 MPa. Compared with $P_{75}B_{25}$ group, the flexural strength of recycled concrete increased slightly to 2.44 MPa when waste polypropylene fibers are added alone.

### *3.4. Splitting tensile strength*

Figure 4 shows the 28-day splitting tensile strength of hybrid fiber recycled concrete with different mixing ratios. It can be seen from the figure that when two kinds of fibers are mixed, the splitting tensile strength of recycled concrete increases with the increase of waste polypropylene fibers dosage. The splitting tensile strength of recycled concrete is 4.55 MPa when waste polypropylene fibers are added alone. And $P_{25}B_{75}$ group is the lowest, which is 1.68 MPa. The splitting tensile strength of recycled concrete is slightly higher than that of $P_{25}B_{75}$ when basalt fibers are added alone, which is 2.37 MPa.

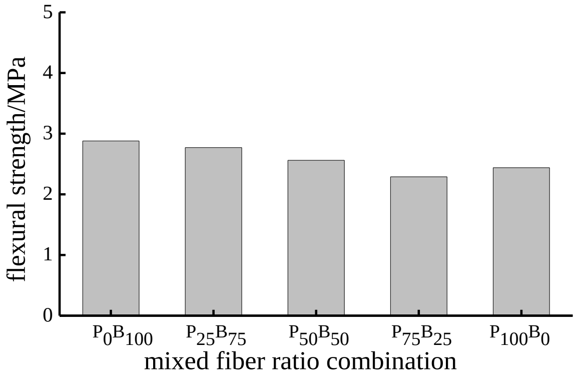


Figure 3. Flexural strength of hybrid fiber recycled concrete with different mixing ratios.

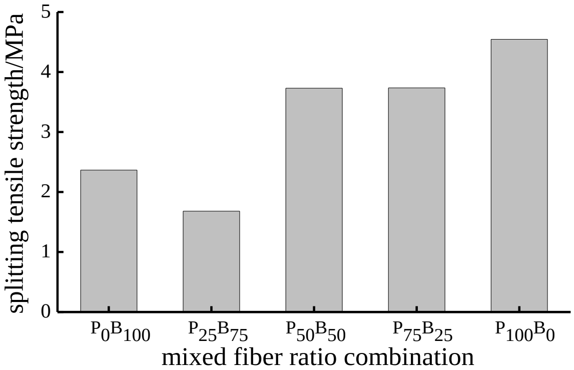


Figure 4. Splitting tensile strength of hybrid fiber recycled concrete with different mixing ratios.

### *3.5. Modulus of elasticity*

Figure 5 shows the 28d modulus of elasticity of regenerated concrete with hybrid fibers of different content. It can be seen from the figure that when two kinds of fibers are mixed, the elastic modulus of recycled concrete increases with the increase of waste polypropylene fibers dosage. The elastic modulus of recycled concrete with waste polypropylene fibers is the largest, which is $2.59\times10^4$MPa. The second highest is the basalt-doped fiber group, which is $2.42\times10^4$MPa. The elastic modulus of $P_{25}B_{75}$ group was the lowest, which was $2.03\times10^4$MPa.

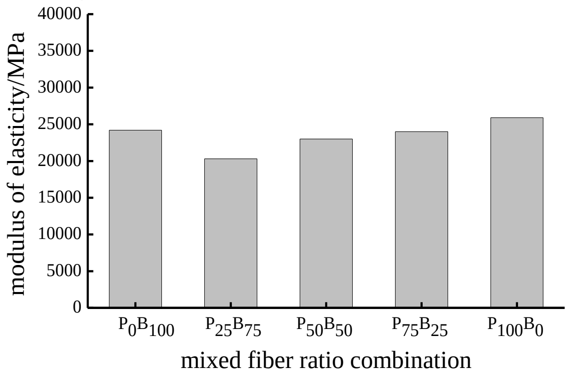


Figure 5. Elastic modulus of hybrid fiber recycled concrete with different mixing ratios.

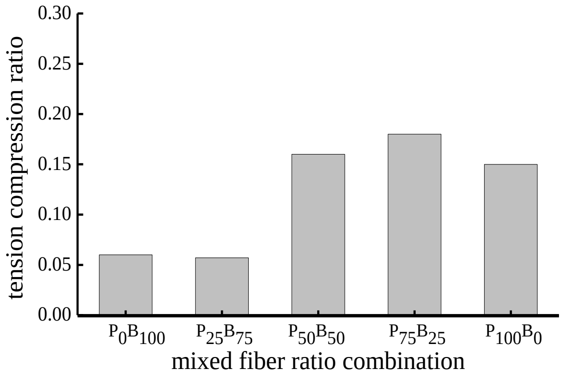


Figure 6. Tension-compression ratio of hybrid fiber recycled concrete with different mixing ratios.

### *3.6. Tension compression ratio*

According to the relevant data, tension compression ratio is the ratio of splitting tensile strength to compressive strength of concrete. The bigger the tension-compression ratio is, the better the crack resistance of concrete is. Figure 6 shows the tension-compression ratio of hybrid fiber recycled concrete with different dosage. It can be seen from the figure that when two kinds of fibers are mixed, the tension-compression ratio of recycled concrete increases with the increase of waste polypropylene fibers dosage. The compression ratio of $P_{75}B_{25}$ group was the highest, which is 0.18; that of $P_{25}B_{75}$

group was the lowest, which is 0.057. This shows that the crack resistance of recycled concrete increases with the increase of waste polypropylene fibers dosage, and the maximum tension-compression ratio of $P_{75}B_{25}$ group shows good crack resistance. The crack resistance of waste polypropylene fibers is better than that of basalt fibers.

### *3.7. Elastic strength ratio*

Elastic strength ratio is the ratio of elastic modulus of concrete to its compressive strength. The smaller the elastic strength ratio is, the better the crack resistance of concrete is. Figure 7 shows the elastic strength ratio of hybrid fiber recycled concrete with different dosage. It can be seen from the figure that the elastic strength ratio reaches the minimum when basalt fibers are added alone. When fibers are mixed, the elastic strength ratio increases gradually with the decrease of basalt fibers content. This shows that the crack resistance of recycled concrete is the best when basalt fibers are added alone. With the decrease of basalt fibers content, the crack resistance of recycled concrete decreases.

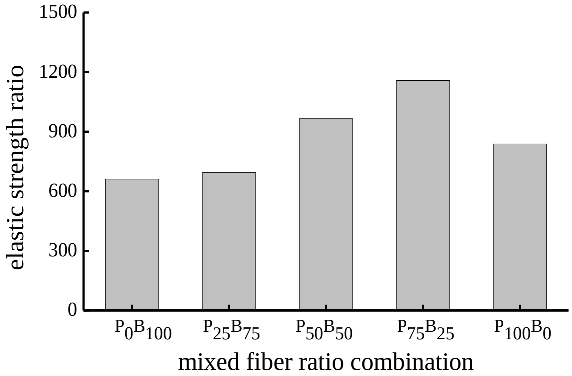


Figure 7. Elastic strength ratio of hybrid fiber recycled concrete with different mixing ratios.

## 4. Conclusion

In this paper, the basic mechanical properties and crack resistance of recycled concrete were studied by changing the mixing ratio of waste polypropylene fibers and basalt fibers. The results are as follows:

(1) When the total blending ratio of fibers is 0.3%, the slump of recycled concrete only changes slightly no matter what proportion of the two fibers are mixed, which indicates that the change of the hybrid fibers content ratio has little effect on the fluidity of recycled concrete.

(2) When fibers are mixed, with the increase of waste polypropylene fibers content, the compressive strength and flexural strength of recycled concrete decrease.

(3) When fibers are mixed, with the increase of waste polypropylene fibers content, the splitting tensile strength and elastic modulus of recycled concrete increase.

(4) When fibers are mixed, with the increase of waste polypropylene fibers, the tension-compression ratio of recycled concrete increases. The brittleness of recycled concrete is improved by increasing the tension-compression ratio.

(5) When fibers are mixed, with the decrease of basalt fibers dosage, the elastic strength ratio increases and the crack resistance of recycled concrete decreases.

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