Study on mechanical properties of slag active powder concrete

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Study on mechanical properties of slag active powder concrete

Zhaopeng Yang¹, Han Deng², Zhipeng Zhao³ and Lu Lu²,*

¹China Grain & Logistics Corporation Beiliang Co., LTD, Dalian, China
²Dalian Jiaotong University, Liaoning Provincial Key Laboratory of New Energy Battery, Dalian, China

*Corresponding author e-mail: piao0215@163.com

Abstract. Concrete with high durability and green environmental protection is an important direction for future research on cement-based materials. As a kind of new building material with super high performance, reactive powder concrete (RPC) will play an important role in future construction. In this paper, slag was selected as the main cementitious material of RPC, and the influence of the content change of the admixture in RPC: steel fiber, glass fiber and polypropylene fiber on the mechanical properties of RPC was studied to analyze and select the optimal dosage of each component and take it as the reference of the optimal mixture ratio of RPC.

1. Introduction

It is well known that in order to produce cement, cement plants have to excavate large amounts of ore and clay. As China’s cement production technology is relatively backward, it is estimated that for every one ton of cement produced, about one ton of CO₂ will be discharged [1]. In the production of power plants, steel mills, iron and aluminum alloy plants, there will also be a large number of industrial waste residue discharge, such as fly ash, slag, silicon powder, which have caused serious damage to our ecological environment [2]. Therefore, how to reduce the amount of cement and increase the recovery and utilization of industrial waste residue is always a topic of concern for cement concrete researchers. The RPC material in this paper was mixed with a large amount of silicon powder, slag and fly ash as the admixture, which not only increased the utilization of industrial waste slag, but also greatly reduced the amount of cement, which was in line with the guidelines for the preparation of green environmental protection materials [3].

2. Experimental

Weigh the quality of each component material exactly according to the blending ratio, add the material in the order of putting, and stir with a blender, dry stirring for 3 minutes, then add the mixed water and water reducing agent and stir until the components are fully mixed, and the fiber is evenly distributed in the mixture. Select the triplex specimen mold of 40 mm * 40 mm * 160 mm, fill it with tamping and place it on the vibrating table for vibration. Make sure that the specimen is filled with the entire mold and the sealing is handled with the side shovel. Cover it with plastic wrap to prevent water evaporation. After 24 hours, remove the mold and observe whether there are large bubbles and unfilled at the edge of the specimen. If so, destroy the unqualified specimen in time and redo it. If the test piece is qualified, mark the code and date of the test piece with the brush and put it into a special curing box.
for room temperature curing. After curing for 28 days, take out the specimens and put them in a ventilated place for air drying. After air drying, conduct folding and compression test.

3. Results and discussion

3.1. Effect of volume ratio of steel fiber on mechanical properties of slag RPC

When improving the toughness of RPC, steel fibers should be added. This experiment mainly studied the influence of the change of the bulk rate of steel fiber on the mechanical properties of slag RPC [4]. The values of compressive and flexural strength of prisms of each group were listed in Table 1 with the mixture ratio in Table 1. In this study, 40 mm*40 mm*160 mm prismatic specimens were used, and there were 5 types of steel fibers with volume ratio: 0%, 0.5%, 1%, 1.5%, 2%. Take Ak1 as an example: A is the test code of this group, k stands for adding slag, and 1 stands for steel fiber volume rate of 0.5%.

| Label | Cement | Sand | Silicon powder | Defoaming agent | Quartz | Slag | Steel fiber | Compressive strength /MPa | Folding strength /MPa |
|-------|--------|------|----------------|-----------------|--------|-----|-------------|---------------------------|----------------------|
| Ak0   |        |      |                |                 |        |     |             | 75.96                     | 18.63                |
| Ak1   |        |      | 0.5            |                 |        |     | 0.5%        | 98.22                     | 19.07                |
| Ak2   | 1      | 1.2  | 0.3            | 0.01%           | 0.3    | S1  |             | 113.52                    | 22.98                |
| Ak3   |        |      |                |                 |        |     | 1.5%        | 125.02                    | 27.43                |
| Ak4   |        |      |                |                 |        |     | 2%          | 125.58                    | 31.26                |

The variation of compressive strength and flexural strength of specimens Ak0-Ak4 is shown in Fig. 1 and Fig. 2 respectively. Through the comparison and analysis of the two figures, the compressive strength and flexural strength of the slag RPC specimens increased with the increase of the steel fiber volume rate, and the compressive strength and flexural strength of the five groups of specimens all presented an upward trend.

Although the increase of steel fiber volume rate can greatly improve the mechanical properties of slag RPC specimens, the excessive mixing may not achieve the ideal effect of engineering application [5]. On the one hand, the increase of the bulk ratio of steel fiber will increase the difficulty of RPC stirring and forming, and even form new weak zones on the bonding surface of fiber and cement paste.
On the other hand, it will greatly increase the cost of production, which is not conducive to the popularization of RPC in the market.

**Table 2. The bend-press ratio of RPC components in different steel fiber’s volume fraction**

| Volume rate of steel fiber (%) | 0      | 0.5    | 1      | 1.5    | 2      |
|--------------------------------|--------|--------|--------|--------|--------|
| Folding strength (Mpa)         | 18.63  | 19.07  | 22.98  | 27.43  | 31.26  |
| Compressive strength (Mpa)     | 75.96  | 98.22  | 113.52 | 125.02 | 125.58 |
| Fold the compression ratio     | 1/4.08 | 1/5.15 | 1/4.94 | 1/4.56 | 1/4.02 |

To sum up, we believe that the volume ratio of steel fiber is appropriate to be 1.5-2%, and the optimal mix ratio of this round test is Ak4 (the volume ratio of steel fiber is 2%) through such factors as bending and pressure ratio.

### 3.2. The influence of the change of polypropylene fiber volume rate on the mechanical properties of slag RPC

In this test, the mechanical properties of RPC were tested by the change of polypropylene volume rate. As a result of the addition of polypropylene fiber, the slurry has a longer mixing time, so that the polypropylene dimension can be mixed as evenly as possible in the concrete. The test was divided into five conditions: 0%, 0.1%, 0.15%, 0.2%, and 0.25%.

**Table 3. The mechanical properties of polypropylene fiber RPC in different volume fraction.**

| Label | Cement | Sand | Silicon powder | Defoaming agent | Quartz | Slag | Steel fiber | Compressive strength /MPa | Folding strength /MPa |
|-------|--------|------|----------------|-----------------|--------|------|-------------|--------------------------|-----------------------|
| Bk0   | P0     |      | 1              | 1.2             | 0.3    | 0.01%| 0.3         | 75.96                    | 19.63                 |
| Bk1   | P0.1   |      | 1              | 1.2             | 0.3    | 0.5  | P0.15       | 97.88                    | 16.26                 |
| Bk2   | 1      | 1.2  | 0.3            | 0.01%           | 0.3    | 0.5  | P0.15       | 93.50                    | 15.47                 |
| Bk3   | P0.2   |      | 1              | 1.2             | 0.3    | 0.5  | P0.25       | 97.60                    | 18.51                 |
| Bk4   | P0.25  |      | 1              | 1.2             | 0.3    | 0.5  | P0.25       | 106.97                   | 16.44                 |

**Figure 3.** The influence of polypropylene fiber’s volume fraction change to compressive strength

**Figure 4.** The influence of polypropylene fiber’s volume fraction change to flexural strength

The changes of compressive strength and flexural strength of specimens Bk0-Bk4 are respectively shown in Fig. 3 and Fig. 4. In this group of specimens, the folding strength of slag RPC did not
increase with the increase of polypropylene fiber volume rate, but decreased. Bk4 specimens have the highest compressive strength, and the fiber volume rate of this group is 0.15%. However, the flexural strength of this group of specimens is not the maximum, but that of plain slag RPC. The maximum compressive strength change is about 30.0 MPa and the variation range is about 40%. The change of folding strength was about 3.0 MPa and the decrease was not significant. Therefore, it can be considered that the folding strength of slag RPC by polypropylene fiber was not affected, but reduced.

The increase of polypropylene fiber volume ratio increases the compressive strength of slag RPC specimens, but reduces the compressive strength instead: the maximum compressive strength is achieved when the polypropylene fiber volume ratio is 0.25%. The strength of plain slag RPC specimens is the greatest, but the resistance of this group is low [6]. According to the folding pressure ratio of specimens, when the volume ratio of polypropylene fiber is 0.2%, the folding pressure ratio is relatively large, which means that the bending capacity is relatively strong. Considering comprehensively, the slag RPC specimen with the volume ratio of polypropylene fiber is 0.2%, which has the best material mixture ratio.

4. Conclusion

Through comparative analysis of the compressive and flexural data of the above three kinds of fiber, it can be seen that the slag RPC specimen with steel fiber has the best mechanical performance, and its compressive strength is 28% and 27% higher than that of the other two kinds of fiber, respectively. The flexural strength was 48% and 49% higher than that of the other two fibers. In view of the excellent performance of Ak3, its mixture ratio is the optimal mixture ratio of this group of experiments. RPC added a large amount of silicon powder and slag as the admixture, which not only increased the use of industrial waste slag, but also greatly reduced the amount of cement, in line with the guidelines for the preparation of green environmental protection materials, but added three different fibers after adding slag to RPC to obtain better mechanical properties.

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