Study on Mechanical Properties of Steel Fiber Rubber Recycled Brick Concrete

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Abstract. In order to study the mechanical properties of steel fiber rubber recycled brick concrete, ten groups of recycled brick concrete specimens with the strength of 15MPa were tested, one group was purely recycled brick concrete, the remaining nine groups mixed with different ratios of admixture. Three groups mixed with steel fiber, another three groups mixed with rubber granules, the last three groups mixed with both steel fiber and rubber granules. These concrete specimens were tested by pressure testing machine respectively, the maximum strength is calculated by its maximum stress value. The results proved that: when adding steel fiber to recycled brick concrete can improve the strength of concrete, the higher the percentage of steel fiber was added, the more obvious the increases in strength. The recycled brick concrete mixed with rubber granules showed a reduced strength of the concrete, the higher percentage of rubber granules were added, the more significant drop in strength. When added the same percentage of both steel fiber and rubber granules, the result showed an increased strength of recycled brick concrete, as the percentage of two kinds of admixture dosage increases simultaneously, the strength increases rapidly.

1 Introduction

As the basic material of the construction industry, reinforced concrete has good plasticity, durability and high compressive strength. In order to reduce the impact of construction waste on the environment, in recent years, many researches have been conducted on recycled concrete materials^[1] containing external admixtures, and experiments have shown that the mechanical properties of single recycled concrete can be improved from different degrees^[2-4]. For example, steel fiber concrete can improve the crack resistance, toughness, durability and impact resistance of concrete materials. The addition of steel fiber mainly affects the splitting tensile strength of concrete. The greater the amount of steel fiber added, the higher the splitting tensile strength increases^[5]. The incorporation of steel fiber can effectively improve the elastic modulus of concrete at 3d time-age^[6]. With the increase of steel fiber volume, the bonding strength between recycled concrete materials can be increased^[7]. The addition of rubber granules to concrete can reduce its density and compressive strength to a certain extent, but improve its fatigue resistance, crack resistance, impact resistance and ductility^[8]. Meanwhile, rubber granules can improve the toughness of concrete^[9-10]. With the increase of rubber granules, the fracture toughness of recycled concrete was tended to increase first and then decrease^[11]. Studies on the early mechanical properties of rubber concrete indicated that the concrete's flexural strength decreases with an increase of rubber granules, the influence of rubber granules size was not obvious, and the time age of

concrete has a significant influence on the cube's compressive strength^[12]. The mixing of steel fiber and rubber granules can work in a coordinated way in the concrete matrix, thus improving the performance of recycled concrete^[13]. From the fire prevention point of view, after the high temperature test, the addition of rubber powder will keep the loudness integrity of the steel fiber concrete specimen and reduce the mass loss. When the amount of dosage is 1%, the specimen's performance conditions, mass loss, residual stress, strain and other physical and mechanical performance can show the peak performance^[14]. In addition, the energy dissipation capacity of steel fiber rubber concrete increases significantly with the addition of rubber, reaching the maximum value when the addition is at 8%^[15]. The amount of rubber granules also affects the air content and compressive strength of recycled concrete^[16].

The above research of recycled concrete is based on crushed concrete as coarse aggregate. There were few researches about recycled brick concrete as coarse aggregate, with admixture of incorporating steel fiber and rubber granules. In view of this, this paper carried out the studies of recycled brick concrete's mechanics performance with adding different dosage of steel fiber and rubber granules.

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2 Test Design

2.1 Test Materials

In order to study the mechanical properties of steel fiber rubber recycled brick concrete, the designed target strength grade was C15. Recycled sintered brick through manual crushing were used as coarse aggregate, the sand was ordinary local river sand, and the cement was 42.5 ordinary Portland cement (Conch brand). The steel fiber used in the mixture was shear wavy steel fiber with a length of 35mm, width of 2mm and thickness of 0.8mm. The rubber granules used in the mixture was made from waste tires with a size of 3-5mm. These two materials are shown in figure 1. Nanning City's drinking tap water was used for concrete mixing and curing.

Figure 1. Steel fiber and rubber granules used in the test

Table 1. Material mix ratio (kg)

Group	Cement	River Sand	Gravel	Water	Steel fiber	Rubber Granules
A	4	8.29	16.52	2.96	-	-
B1	4	8.29	16.52	2.96	0.297	-
B2	4	8.29	16.52	2.96	0.594	-
B3	4	8.29	16.52	2.96	0.891	-
C1	4	8.29	16.52	2.96	-	0.03
C2	4	8.29	16.52	2.96	-	0.059
C3	4	8.29	16.52	2.96	-	0.089
D1	4	8.29	16.52	2.96	0.297	0.03
D2	4	8.29	16.52	2.96	0.594	0.059
D3	4	8.29	16.52	2.96	0.891	0.089

2.2 Concrete Proportion Design

There were 10 groups of test specimens were made for comparative test. The first Group A, original recycled brick concrete with the target strength value of 15MPa, component materials included recycled brick, local river sand, gravel and water. The remaining 9 groups concrete materials were used the group A's design proportion, and added different dosage of admixtures in each group. Record them as in Group B, added 1% steel fiber (Group B1), 2% steel fiber (Group B2) and 3% steel fiber (Group B3) respectively. In group C, added 1% rubber granules (Group C1), 2% rubber granules (Group C2)

and 3% rubber granules (Group C3) respectively. Whereas in Group D, added both steel fiber and rubber granules simultaneously in one group, the dosages were 1% steel fiber and 1% rubber granules (Group D1), 2% steel fiber and 2% rubber granules (Group D2), 3% steel fiber and 3% rubber granules (Group D3). The combination of specimens were shown in Table 1.

The concrete mould was a 150x150x150mm cube. The mould was disassembled after the concrete has set, and then placed them into curing tank for 4 weeks. Afterward, these specimens were taken out and dried before experiment which is shown in Figure 2, the compressive test was carried out of each specimens.

Figure 2. Recycled brick concrete specimens

2.3 Test Equipment

The experiment was carried out in the Civil Engineering Laboratory of Nanning University. The instrument was a YE-2000C Pressure Testing Machine with a maximum loading load of 2000kN and a loading speed of 0.3MPa/s. The test equipment is shown in Figure 3.

Figure 3. Test Equipment

3 Result Analysis

3.1 Process of Simulation Test

Compressive Strength Test was carried out on concrete specimens until the load cannot proceed, then unloading after each test. The partially damaged of test specimen is shown in Figure 4. It can be seen from figure 4 that the crack started at the bottom corner of the test specimen

and gradually develop to the middle, the damage form was similar to the triangular shape.

Figure 4. Damage condition of test specimen

3.2 Test Results

The Pressure Testing Machine was used to load each specimen successively, the load peak value of each group was recorded. The maximum load value obtained is shown in Table 2.

Table 2. Maximum load value of each group (kN)

Group	Specimens1	Specimens2	Specimens3	Average value
A	410.48	422.8	432.56	421.95
B1	407.76	444.55	423.81	425.37
B2	446.42	458.42	438.44	447.76
B3	502.44	496.55	494.85	497.95
C1	412.53	424.69	416.73	417.98
C2	402.40	414.96	417.11	411.49
C3	394.94	407.74	403.73	402.14
D1	419.86	438.49	441.73	433.36
D2	437.92	454.62	446.12	446.22
D3	464.49	468.5	464.99	465.99

The strength conversion of load values in Table 2 is carried out, formula 1 is adopted for conversion.

$$f = \frac{F}{A} \quad (1)$$

Where, A is the area of the specimen. That is $A=150 \times 150 \text{ mm}^2$.

The calculated compressive strength and average strength values of each test specimen is shown in Table 3.

From Table 3, Group A is the recycled brick concrete with the target strength of 15MPa. After the test, the minimum strength of Group A is 18.24Mpa, the maximum strength is 19.22Mpa, and the average strength is 18.75mpa, the strength meets the target requirements. The average strength of Group B1 with 1% steel fiber was 18.91Mpa, that of Group B2 with 2% steel fiber was 19.90Mpa, and Group B3 with 3% steel fiber was 22.13mpa. The overall strength of Group B was increased. Compared with Group A, the strength of

Group B1 increased by 0.81%, Group B2 increased by 6.12%, and Group B3 increased by 18.01%. The results showed that the strength of recycled brick concrete can be improved by adding steel fiber. The influence of steel fiber on strength was not obvious when the dosage of steel fiber is less than 1%, but the strength increase rapidly with an increase of the dosage of steel fiber.

Table 3. Maximum strength values of each group (MPa)

Group	Specimens 1	Specimens 2	Specimens 3	Average value
A	18.24	18.79	19.22	18.75
B1	18.12	19.76	18.84	18.91
B2	19.84	20.37	19.49	19.90
B3	22.33	22.07	21.99	22.13
C1	18.33	18.88	18.52	18.58
C2	17.88	18.44	18.54	18.29
C3	17.55	18.12	17.94	17.87
D1	18.66	19.49	19.63	19.26
D2	19.46	20.21	19.83	19.83
D3	20.64	20.82	20.67	20.71

For Group C, added 1% rubber granules, the strength of the average was 18.58MPa, added 2% the strength average of Group C2 was 18.29MPa, added 3% the strength average of Group C3 was 17.87MPa. The overall strength of Group C showed a downward trend. Compared with Group A, Group C1 was reduced by 0.94%, C2 was reduced by 2.48% and C3 intensity was reduced by 4.69%. The results showed that adding rubber granules to the recycled brick concrete will reduce the strength of concrete. There was not obvious effect on the strength reduction when the percentage is smaller than 1%. However, with an increase percentage of added rubber granules, the strength will decrease significantly.

For added 1% steel fiber and 1% rubber granules at the same time in Group D1, the average strength was 19.26MPa. The strength average of Group D2 was 19.83MPa which was added the 2% steel fiber and 2% rubber granules, and added 3% steel fiber and 3% rubber granules of Group D3, the average was 20.71MPa. The strength of Group D showed an overall upward trend. In compared to Group A, strength of Group D1 was increased by 2.70%, Group D2 was increased by 5.75%, and Group D3 was increased by 10.44%. The results showed that adding the same dosage of steel fiber and rubber granules has increased the strength of recycled brick concrete. Also it shown that with an increase of admixture dosage of steel fiber and rubber granules added at the same time, the strength increases rapidly.

Lastly, Compare Group B with Group D, the average strength of Group B1 with added 1% steel fiber was slightly lower than Group D1 with added 1% steel fiber and 1% rubber granules. The reason for this result may be due to experimental error. The average strength of Group B2 with 2% steel fiber was greater than that of Group D2 with 2% steel fiber and 2% rubber granules. Compared Group B3 which added 3% steel fiber with

Group D3 that added 3% steel fiber and rubber granules, the average strength of Group B3 was greater than that of Group D3. The result showed that adding rubber granules to steel-fiber brick concrete can reduce the strength of the concrete, with the increase of admixture dosage of rubber granules added into the concrete, the strength decreases obviously.

4 Conclusion

In order to study the mechanical properties of steel fiber rubber recycled brick concrete, 10 groups of total 30 specimens with different dosage of steel fiber and rubber granules added into the recycled brick concrete, they were designed for the strength test and calculation analysis. The conclusions are as follows:

A. Adding steel fiber to recycled brick concrete can improve the strength of recycled brick concrete. As an increase dosage of steel fiber, the strength increases obviously. Added rubber granules to recycled brick concrete will reduce the strength of concrete. When there is an increase dosage of rubber granules add into the concrete, the recycled brick strength concrete will decrease significantly.

B. Adding the same dosage of steel fiber and rubber granules will increase the strength of recycled brick concrete. When there is an increase dosage of both admixtures add at the same time, the recycled brick concrete strength will increase rapidly.

Thus, in view of the characteristics of steel fiber rubber concrete, it is suggested that this material can be used in urban and rural areas' road and bridges engineering projects, especially for the surface section of a road or bridges structure that needs to increase both flexibility and strength.

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