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STRENGTHS OF RECYCLED CONCRETE ADDED WITH STEEL FIBER

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The strength of recycled aggregate (RA) is low, which makes the performance of recycled aggregate concrete (RAC) poor, and the addition of fiber can make up for the shortcoming of RAC. In this paper, the mechanical properties of RAC which was added with steel fiber were studied. The specimens with RA content of 0%, 40%, 70% 100% and steel fiber content of 0%, 0.5% and 1% were prepared, and their mechanical properties were tested. The results showed that the slump reduced 73.75% after the addition of 100% RA and 37.5% after the addition of 1% steel fiber compared to R0S0; from the perspective of mechanical properties, the larger the content of steel fiber, the better the mechanical properties of the specimen; the improvement of the tensile strength was the most obvious after the addition of steel fiber. The experimental results show that steel fiber can improve the performance of RAC and make it perform better in practical application.

Keywords: recycled aggregate concrete, steel fiber, slump, compressive strength, flexural strength

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1. INTRODUCTION

With the development of society and the needs of urban construction, concrete, as the most basic building material, has been increasing in consumption and made a great contribution to urban construction. The generation of concrete requires a large amount of aggregate [1], i.e., sand and gravel. The increase of concrete demand also causes the increase of sand and gravel demand, while the amount of sand and gravel is limited. In addition, the development of urban construction also brings a lot of waste concrete. In order to deal with waste concrete reasonably, it can be used to produce recycled aggregate concrete (RAC), which solves the environmental problem caused by waste concrete [2] and has high economic, social and environmental benefits [3]. Research on RAC has been widely concerned by researchers. Based on the digital image of nano indentation, Wang et al. [4] made a finite element analysis of RAC and found that the replacement rate of recycled aggregate (RA) could significantly affect the overall performance of the structure. Guo et al. [5] studied the mix proportion of RAC, analyzed the influence of cementitious material content and RA replacement rate on RAC performance, and found that the optimized mix proportion could reduce the compressive strength of RAC by only 6.4 MPa compared with natural concrete and the water consumption was only 7.1%. Juez et al. [6] studied the brittleness of RA in the mixing process and found that the mass loss of natural aggregate was small, the mass loss rate of RA was high, but the RA after mixing was more smooth. Wu et al. [7] studied the fracture performance of RAC and found that RA had no obvious effect on crack initiation and its fracture performance would not decrease with the increase of RA content. Nuaklong et al. [8] studied the application of RA in fly ash based polymer concrete and found that the compressive strength of RA as coarse aggregate was slightly lower than that of the coarse aggregate of crushed limestone. Tam et al. [9] analyzed the drying shrinkage and creep deformation behavior of RAC and found that the drying shrinkage and creep behavior increased with the increase of RC content and the water cement ratio and aggregate cement ratio had little effect on the deformation. Carneiro et al. [10] studied the effect of steel fiber on the stress-strain properties of RAC through designing concrete with 0.75% volume fraction of steel fiber and found that the behavior of the concrete under compression was similar to that of natural aggregate concrete and the toughness was improved. Ramesh et al. [11] compared the properties of specimens with different steel fiber volume fractions and RA replacement rate, and found that the tensile strength and compressive strength of specimens decreased with the increase of RA content and the split-tensile strength and compression toughness of specimens increased with the increase of steel fiber content.

In order to improve the mechanical properties of RAC, steel fiber was added to RAC in this study, and the change of RAC performance was studied. It was found that steel fiber had little influence on the compressive strength of RAC, but had good improvement effect on the tensile and bending strength, which makes some contributions to its better application in practical engineering.

2. RECYCLED CONCRETE

RA needs to be broken and screened for many times to remove impurities such as steel bars, wood blocks and glass, so as to obtain high-quality RA. Compared with natural aggregate, RA has: ① rough surface, with porosity [12]; ② high water absorption; ③ a small apparent density; ④ has low strength because of the long-time use before waste; ⑤ poor wear resistance.

Due to the characteristics of RA, the mechanical properties of RAC are quite different from those of ordinary concrete. In order to make up for these defects, some fibers can be added to improve the mechanical properties of RAC [13]. The addition of metal, organic or inorganic fibers [14] in fiber concrete (FC) can effectively improve the defect of concrete [15], and steel fiber reinforced concrete has been widely studied by virtue of its excellent performance [16]. At present, steel fiber is mainly used in the modification of ordinary concrete [17,18], and its application in RAC is rarely studied.

3. MATERIALS AND METHODS

3.1 MATERIALS

Cement: P·O 42.5R cement, Hubei Jinglan Cement Group Co., Ltd

Coarse aggregate: gravel, Zhengzhou Sijihuo Refractory Material Co., Ltd

Fine aggregate: medium sand, Henan Tengze Environmental Protection Technology Co., Ltd

RA: being obtained after processing waste concrete beam from a factory

Superplasticizer: polycarboxylate superplasticizer, Shenyang Xingzhenghe Chemical Co., Ltd

Steel fiber: shear type (ratio of length to diameter: 38), Xi'an Aide Construction Engineering Co., Ltd.

Water: tap water

The properties of the two coarse aggregates are shown in Table 1.

Table 1. Properties of coarse aggregate

	Gravel	RA
Apparent density/(kg/m3)	2800	2550
Water absorption/%	1.02	4.17
Water content/%	0.5	0.4
Crushing index	9.1	11.5

3.2 PREPARATION OF TEST SPECIMENS

The concrete strength designed in this study was C30, and the mix proportion was: cement: water: sand: gravel: water reducer = 430:185:571:1214:2.65. Different content of RA was used to replace the gravel in the concrete, and different content of steel fiber was added. The designed test specimens are shown in Table 2.

Table 2. Number and design of different test specimens

Specimen number	RA content/%	Steel fiber content/%
R0S0	0	0
R0S0.5	0	0.5
R0S1	0	1
R40S0	40	0
R40S0.5	40	0.5
R40S1	40	1
R70S0	70	0
R70S0.5	70	0.5
R70S1	70	1
R100S0	100	0
R100S0.5	100	0.5
R100S1	100	1

3.3 MECHANICAL PROPERTY TEST

The slump of the test specimen was calculated according to GB/T50080-2002, and the test specimen was tested according to GB/T 50081-2002. The compressive strength test was carried out by JES-2000A pressure testing machine, and the test specimen was placed in the center of the lower pressing plate. The loading speed was kept between 11.25-18 kN/s, and the compressive strength was calculated according to $f = \frac{F}{A}$, where F is the failure load and A is the bearing area of the test specimen. The tensile strength test was carried out by 1000kN electric-servo universal testing machine, with the center line aligned, and the loading speed was kept at 0.08 Mpa/s. The tensile strength was calculated according to $f' = 0.637\frac{F'}{A'}$, where F' is the failure load of the test specimen and A is the area of split surface. The bending strength test was carried out by WE-600B universal testing machine. The test specimen was placed in the clamp. The loading speed was kept at 50 N/s ± 10 N/s. The bending strength was calculated according to $f'' = \frac{F_{\max} l}{bh^2}$, where $F_{\max}$ refers to the maximum load, l refers to spacing of support, and b and h are the width and height of section.

4. EXPERIMENTAL RESULTS

4.1 SLUMP

The slump of different concretes is shown in Fig. 1.

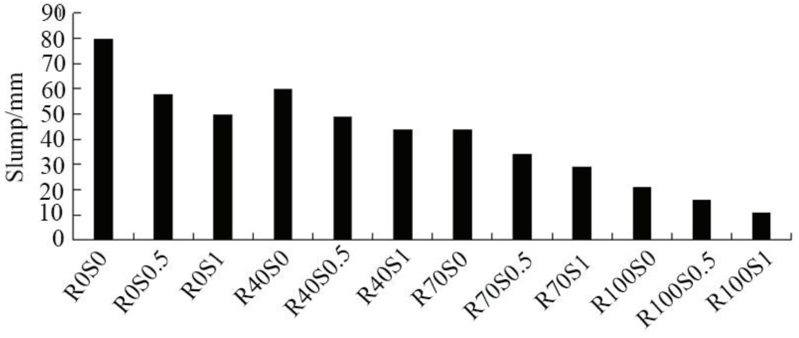

Fig. 1. The slump of the test specimens

It was seen from Fig. 1 that the slump decreased gradually with the increase of RA and steel fiber content. First of all, from the point of view of the addition of RA, the higher the content of RA, the smaller the slump, and the slump of R100S0 was 73.75% lower than that of R0S0. Then, from the point of view of the addition of steel fiber, the higher the content of steel fiber, the smaller the slump, and the slump of R0S1 was 37.5% lower than that of R0S0.

4.2 COMPRESSIVE STRENGTH

The compressive strength of different test specimens is shown in Table 3 and Fig. 2.

Table 3. The compressive strength of different test specimens

	Compressive strength/MPa
R0S0	45.6
R0S0.5	46.7
R0S1	48.5
R40S0	44.6
R40S0.5	45.4
R40S1	47.8
R70S0	40.6
R70S0.5	42.2
R70S1	45.8
R100S0	39.8
R100S0.5	40.5
R100S1	42.6

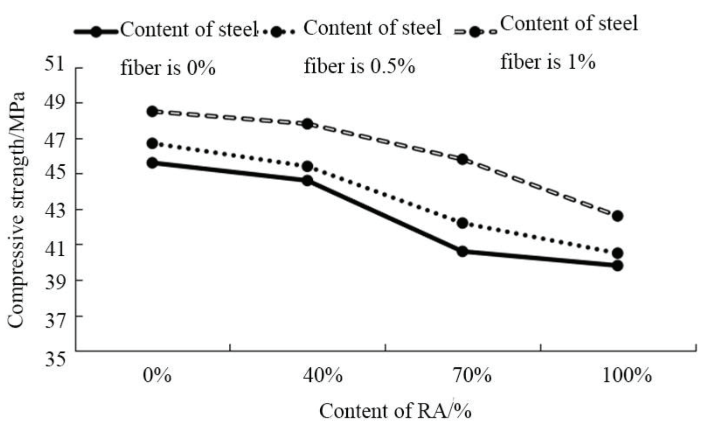

Fig. 2. Changes of compressive strength

It was seen from Fig. 2 that the compressive strength of different test specimens decreased gradually with the increase of RA content. Table 3 shows that the compressive strength of R100S0 was 12.72% lower than that of R0S0; but when the content of RA was the same, the higher the content of steel fiber, the higher the compressive strength of the test specimen. When the content of RA was 0%, the compressive strength of R0S0.5 and R0S1 was 2.41% and 6.36% higher than that of R0S0; when the content of RA was 40%, the compressive strength of R40S0.4 and R40S1 increased by 1.79% and 7.17% respectively compared with R40S0; when the content of RA was 70%, the compressive strength of R70S0.5 and R701 increased by 3.94% and 12.8% respectively compared with R70S0; when the content of RA was 100%, the compressive strength of R100S0.5 and R100S1 increased by 7.04% and 7.04% respectively compared with R100S0.

4.3 TENSILE STRENGTH

The tensile strength results of different test specimens are shown in Table 4 and Fig. 3.

Table 4. The tensile strength of different test specimens

	Tensile strength/MPa
R0S0	2.85
R0S0.5	3.25
R0S1	3.69
R40S0	2.72
R40S0.5	3.16
R40S1	3.45
R70S0	2.52
R70S0.5	2.92
R70S1	3.22
R100S0	2.22
R100S0.5	2.69
R100S1	3.08

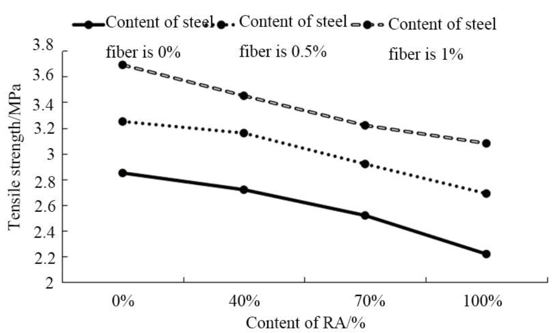

Fig. 3. Changes of tensile strength

It was seen from Fig. 3 that the tensile strength of the test specimen decreased with the increase of RA content. Table 4 shows that when the content of RA was 0%, the tensile strength of R0S0.5 and R0S1 was 14.04% and 29.47% higher than that of R0S0; when the content of RA was 40%, the tensile strength of R40S0.5 and R40S1 was 16.18% and 26.84% higher than that of R40S0; when the content of RA was 70%, the tensile strength of R70S0.5 and R70S1 was 15.87% and 27.78% higher than that of R70S0; when the content of RA was 100%, the tensile strength of R100S0.5 and R100S1 was 20.72% and 38.74% higher than that of R100S0.

4.4 BENDING STRENGTH

The bending strength of different test specimens is shown in Table 5 and Fig. 4.

Table 5. The bending strength of different test specimens

	Bending strength/MPa
R0S0	5.52
R0S0.5	5.93
R0S1	6.42
R40S0	5.29
R40S0.5	5.84
R40S1	6.26
R70S0	5.27
R70S0.5	5.68
R70S1	5.91
R100S0	4.86
R100S0.5	5.31
R100S1	5.74

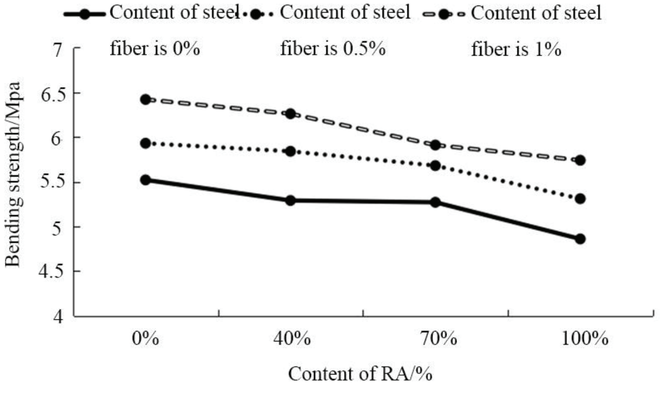

Fig. 4. Changes of bending strength

It was seen from Fig. 4 that the higher the content of steel fiber, the greater the bending strength. Table 5 shows that when the content of RA was 0%, the bending strength of R0S0.5 and R0S1 increased by 7.43% and 16.3% respectively compared with R0S0; when the content of RA was 40%, the bending strength of R40S0.5 and R40S1 increased by 10.4% and 18.34% respectively compared with R40S0; when the content of RA was 70%, the bending strength of R70S0.5 and R70S1 increased by 7.78% and 12.14% compared to R70S0; when the content of RA was 100%, the bending strength of R100S0.5 and R100S1 increased by 9.26% and 18.11% respectively compared with R100S0.

5. DISCUSSION

The reuse of waste concrete and RAC has been well developed in China and abroad [19]. At present, RAC is mostly used in the construction of foundation and pavement [20], which belongs to low-strength concrete. In order to improve the performance of RAC, the effect of steel fiber on the mechanical properties of RAC was studied in this study.

According to the slump results, the addition of RA and steel fiber is not conducive to the fluidity of concrete. RA is rougher than gravel, with large porosity, large water absorption, and more cement paste absorbed, thus reducing the fluidity of paste. In addition, the addition of steel fiber increases the friction, and in order to wrap steel fiber, more cement paste needs to be consumed, which further reduces the slump.

According to the results of compressive strength, the compressive strength of specimens decreased with the increase of RA content, and increases with the increase of steel fiber content. The strength of RA is lower than that of crushed stone, and there are many cracks after crushing, so the strength of concrete will decrease to a certain extent, and the addition of steel fiber can increase toughness, absorb energy, and improve the compressive strength of the specimen.

According to the results of tensile strength and bending strength, the higher the content of RA, the lower the tensile strength and bending strength of the test specimen because of the low strength of RA. The addition of steel fiber can improve the deformation resistance of concrete, prevent the expansion of cracks, and strengthen the tensile strength and bending strength.

In this study, RAC was studied and some results were achieved, but there are still some problems not considered, such as:

(1) exploring the optimal mix proportion by improving the content of steel fiber;

(2) analyzing the anti-fatigue and anti-carbonization properties of the specimens which are added with with steel fiber; (3) studying the structural performance of steel fiber added RAC.

6. CONCLUSION

In this study, the mechanical properties of RAC which was added with steel fiber were studied. Through the design and experiment of the test specimen, it was found that:

(1) the addition of RA and steel fiber reduced the slump of concrete;

(2) the strength of RA was low; therefore the higher the content of RA, the worse the mechanical property of the test specimen;

(3) the addition of steel fiber improved the mechanical properties of RAC, especially the tensile strength.

The tensile and bending strength of RAC has close correlation with the practical application of RAC. The better the tensile and bending strength were, the wider the application scope was. The research verifies that steel fiber can improve the mechanical properties of RAC and provides some theoretical support for the further application of RAC in engineering construction, which is conducive to promoting the better use of waste concrete.

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LIST OF FIGURES AND TABLES:

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