Experimental study on fracture properties of Waste fiber recycled concrete

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Abstract. In order to study the influence of the replacement ratio of recycled aggregate and the volume of waste fiber on the fracture performance of concrete, the three-point bending test is carried out on the waste fiber recycled concrete precast beams. Calculate the waste recycled fiber concrete fracture parameters according to the double-K fracture model. The results show that the fracture indexes of recycled fiber are related to the recycled aggregate replacement ratio and the volume content of waste fiber. The larger the replacement rate of recycled aggregate is, the smaller the fracture indexes of the specimens are. The volume content of waste fiber is 0.12%, which has the most significant effect on the fracture performance. The study shows that waste fiber can improve the fracture properties of recycled aggregate concrete.
Key words. recycled concrete; waste fiber; fracture criteria; fiber volume content

1 Introduction

As the environmental and resource issues have become increasingly prominent, the application of recycled concrete conforms to the development trend of green building. There are micro cracks in recycled concrete, and it has been found that the mechanical properties of recycled concrete are worse than ordinary concrete [1-3]. Fiber can improve the mechanical properties of recycled concrete. Therefore, in-depth study of fiber-recycled concrete has great significance for promoting the development of recycled concrete [4-6]. Cracks are an important factor affecting the quality and durability of concrete. How to control the generation and propagation of cracks effectively is the most important problem of fiber-recycled concrete.

The waste fibers can constrain the development of micro-cracks. Currently, the research on fiber recycled concrete is still in service behavior, basic mechanical function and durability [7-9]. In this paper, using three-point bending fracture tests，the study is carried out on the fracture properties of waste fiber recycled concrete with diffident replacement ratio of recycled aggregate and fiber volume.

2 Experiment

2.1 Materials

Ordinary Portland cement (P.O.42.5) with physical properties shown in Table 1 is used in this study. The fine aggregate is ordinary river sand with fineness modulus of 2.7, moisture content of 4.15% and apparent density of 2610kg/m³. There are two kinds of coarse aggregate, one for nature gravel and the other for recycled aggregate. Recycled aggregate from the abandoned concrete beams in laboratory of Shenyang Jianzhu University, the initial intensity is C40. After artificial crush and then through the jaw crusher, the recycled coarse aggregate is obtained and basic properties of recycled coarse aggregate indicators are shown in Table 2. Two kinds of coarse aggregate with gradation within 5~20mm, the maximum should be less than 25mm. The waste fibers are from waste polypropylene fiber carpet, which is split into length of 19mm.

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Table 1 Physical Properties of Cement

surface area (m^3/kg)	Consistency (%)	setting time		stability	compressive strength (MPa)		flexural strength (MPa)	
		initial setting	final setting		3d	28d	3d	28d
348	25.0	2.3h	3.5h	eligible	25.9	43.6	5.9	9.1

Table2 Physical Properties of recycled aggregate

Index project	apparent density (kg/m^3)	bulk density (kg/m^3)	crush index (%)	water absorption (%)	moisture content (%) max	moisture content (%) min
recycled aggregate	2461.0	1167.6	17	4.18	1.10	0.47
					0.83	

2.2 Test methods

Place a 3mm steel plate in the cross of the specimen, form 3mm preformed joint after maintenance for 24 hours, and then cure 28 days under natural conditions. The specimen size and breaking performance test are shown in Figure 1.

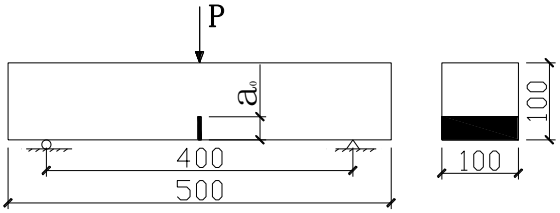


Figure 1. Schematic of breaking performance test

By using hydraulic jacks manually in the test, the load is applied with a loading speed of 0.02kN/s. The data are recorded in the DH3816N static strain test system. The main contents of this test are as follows: cross deflection of precast cracks，load-middle span displacement, load-crack mouth opening strain and load- crack tip opening strain. The recycled aggregate replacement rate and waste fiber volume fraction are the design variables. The specimen grouping is listed in Table3.

Table3 Specimen grouping

Series	Specimen size（mm）	Initial crack-depth ratio	Recycled aggregate replacement ratio（%）	Fiber length（mm）	Fibers content (%)
F1	500×100×100	0.3	0	19	0.12
F2	500×100×100	0.3	100	19	0.12
F3	500×100×100	0.3	50	0	0
F4	500×100×100	0.3	50	19	0.08
F5	500×100×100	0.3	50	19	0.12
F6	500×100×100	0.3	50	19	0.16

3 Results and discussion

3.1 Phenomena and results

Before waste fiber recycled concrete cracking, cracks expand slowly in the concrete, waste fiber plays a role in the junction in preventing the development of cracks. The plastic zone is formed in the connection of the waste fiber and the crack. In addition, when the load reaches the intensity of the crack strength, the specimens of waste fiber will produce a certain amount of load mutation, but fracture damage phenomenon has an obvious distinction with or without waste fiber. Waste fiber recycled concrete three-point bending beam after the load mutates, can continue to bear a greater load, and result in large deformation, until some or all of the waste fibers are pulled out of the test pieces to appear fracture damage of instability.

Fracture performance indicators of waste fiber recycled concrete are shown in Table 4. From the experimental results, the curve of load-crack mouth

opening displacement ($CMOD_c$) and the load- crack tip opening displacement ($CTOD_c$) are obtained. Fracture parameters is calculated based on double - K fracture criterion proposed by Shilang Xu[10]. In the critical condition:

$$K_{IC}^{ini} = K_{IC}^{un} - K_{IC} \quad (1)$$

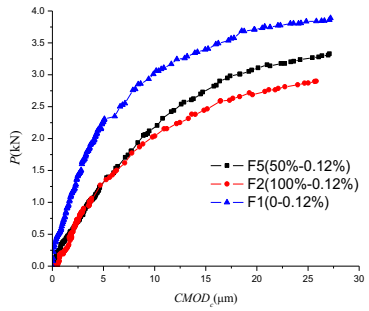
Where K_{IC}^{ini} is initial fracture toughness, K_{IC}^{un} is unstable fracture toughness, K_{IC} is stress intensity factor.

Table 4 Fracture performance indicators of waste fiber recycled concrete

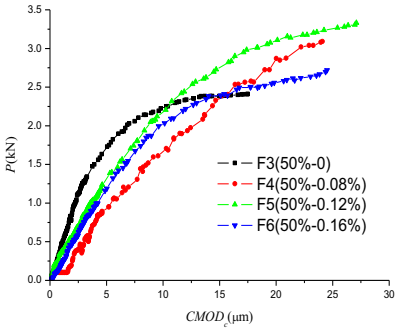
Series	$CMOD_c$ (μm)	effective crack length a_c (mm)	$CTOD_c$ (μm)	K_{IC}^{ini} (MPa m$^{1/2}$)	K_{IC}^{un} (MPa m$^{1/2}$)	K_{IC} (MPa m$^{1/2}$)
F1	27.2	41.59	12.13	0.74	1.81	1.06
F2	25.8	41.64	11.52	0.43	1.35	0.92
F3	17.5	38.68	7.02	0.48	1.03	0.56
F4	24.1	40.67	10.44	0.36	1.40	1.04
F5	27.1	41.58	12.08	0.33	1.55	1.22
F6	24.5	43.76	11.58	0.37	1.34	0.97

3.2 curve of *P-CMOD$_c$*

The *P-CMOD$_c$* curve of waste fiber recycled concrete precast beam is shown in Figure 2. Figure 2 (a) is the influence of the replacement rate of recycled aggregate and figure 2 (b) is the influence of volume fraction of waste fiber on the curve.



(a)the influence of the replacement rate of recycled aggregate



(b) the influence of volume fraction of waste fiber

Figure 2. circumstances of *P-CMOD$_c$*

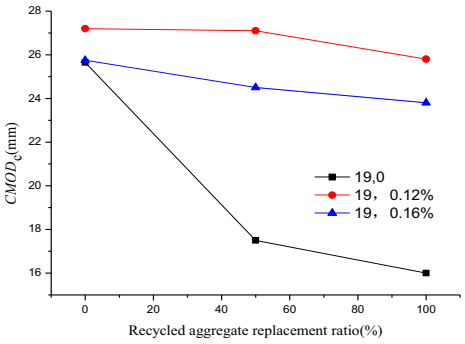
As shown in Fig.2(a), the P-CMODc curve of natural concrete is above the other two curves. The smaller the replacement rate of recycled aggregate is, the greater the maximum crack load of recycled fiber recycled concrete is. The cracking load of recycled concrete specimens with replacement ratio of 50% and 100% is lower than that of the natural aggregate concrete by 29.6% and 34.2%. This shows that the greater the replacement rate of recycled aggregate is, the weaker is the ability of concrete to resist the development of micro and macro cracks growth and development.

It can be seen from Fig.2 (b), when the fiber length is 19mm, the curve of the test piece F5 is above the other curves. The average cracking load of waste fiber volume fraction of 0.08%, 0.12% and 0.16% is increased by 28.2%, 38.2% and 12.9%, respectively, compared with that of non - fiber specimens. The replacement rate of recycled aggregate is 50%, the fiber length is 19mm, the volume content is 0.12%, the maximum cracking load of recycled aggregate concrete.

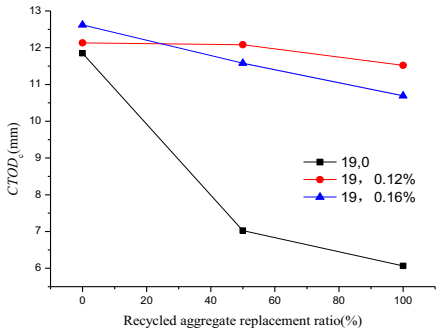
The reasons for recycled concrete cracking load bigger than ordinary concrete are as the following three points. First of all, the mixing process is required to increase the amount of water in order to maintain the performance of recycled concrete; Secondly, there is a big difference between hardened cement mortar and new cement mortar. Due to the difference between hardened cement mortar and new cement mortar, there is a weak area in concrete. Finally, the initial damage and secondary injury cause a large number of micro cracks in recycled concrete. Waste fiber can improve the maximum cracking load of recycled concrete, and the optimal volume content of waste fiber is 0.12%.

3.3 Fracture toughness

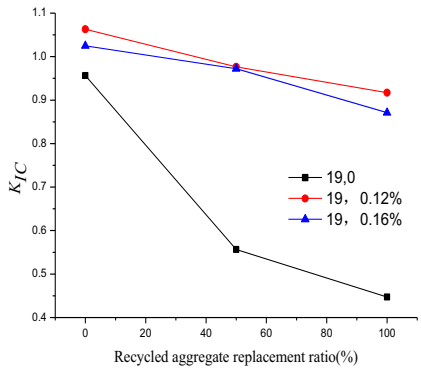
The fracture index $CMOD_c$, $CTOD_c$ and K_{CI} decreases with the increase of recycled aggregate replacement rate, as illustrated in Fig.3.



(a) $CMOD_c$



(b) $CTOD_c$



(b) K_{CI}

Figure 3. fracture parameters change with recycled aggregate replacement ratio

Compared with the replacement rate of 100% of the waste fiber concrete specimens, replacement ratio is 0 and 50% specimens of the $CMOD_c$ increases about 9.4%~60.3%, $CTOD_c$ increases about 15.8%~95.2% and the K_{CI} increases about 6.4%~15.9%. The greater the rate of recycled aggregate is, the worse the fracture properties of waste fiber recycled concrete is.

When the fiber length is 19mm and the volume content is 0.12%, the three indexes are decreased with the increase of the replacement rate of the recycled aggregate. The replacement rate is 100%, and the fracture index is the smallest. Recycled aggregate ratio of 0 and 50% the $CMOD_c$ upgrading from 5.4% to about 9.3%, the $CTOD_c$ lift about 4.9% ~ 5.3%, lifting the K_{CI} about 6.4% - 8.9%.

When the fiber length is 19mm and the volume content is 0.16%, the recycled aggregate ratio of 0 and 50% of the $CMOD_c$ increased by 5.1% ~ 8.2%, the $CTOD_c$ increase from 8.3% to 18.1% and the K_{CI} improve the 11.6%~17.7%.

With the increase of recycled aggregate replacement rate, the original defects increase and the maximum cracking load was decreased. The fracture and other mechanical properties of the recycled concrete are also deteriorated with the increase of the replacement rate of the recycled aggregate.

4 Conclusions

The following conclusions can be drawn from the results of the three-point bending fracture tests:

(1) According to the three-point bending fracture tests of waste fiber recycled concrete precast beam based on the study of double-K fracture criterion, waste fibers can significantly improve the fracture properties of recycled concrete.

(2) The fracture indexes of the specimen become smaller with the increase of the replacement ratio of recycled aggregate. The addition of recycled aggregates reduces the fracture properties of the specimens.

(3) The replacement rate of recycled aggregate is 50%, waste fiber length is 19mm, and volume content is 0.12%, the fracture performance of the specimen is the best, followed by volume content is 0.08%. When waste fiber volume content is 0.16%, the fiber is difficult to disperse in the concrete and forms an area of weakness, thus the fracture properties of the specimen decrease.

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