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Finite Element Simulation Analysis on Crack Resistance of Recycled Concrete Beams of Hybrid Fiber with Waste Polypropylene Fiber

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Abstract: In order to improve the recycling efficiency of construction waste and reduce the environmental pollution, the recycled coarse aggregate was processed into recycled coarse aggregate instead of some natural coarse aggregate, and recycled concrete was prepared in this paper. The influence of the total blending ratio of recycled concrete on the crack resistance of recycled concrete beams was simulated by finite element method, and the ratio of recycled polypropylene fiber and common polyacrylonitrile fiber was changed according to a certain proportion of recycled concrete fiber. The results show that the crack resistance of recycled concrete beams can be improved effectively by adding waste hybrid fibers, which can be used as fiber reinforced materials to improve the properties of recycled concrete beams.

1. Introduction

In recent years, with the rapid development of the construction industry, many old buildings with low utilization rate have been demolished and rebuilt, resulting in a large amount of construction waste. Relevant data[1] shows that the amount of construction waste in China has accounted for 30%~40% of the total amount of urban garbage. According to the standard of 500~600 tons per 10,000 square meters, by 2020, China will also add about 30 billion square meters of construction area. Among them , the waste concrete is up to 35 %~50% of the total domestic waste . In addition, with the increasing improvement of people's quality of life, the textile industry in China has also developed rapidly, but the following waste products are also increasing day by day. According to the statistics of the Ministry of Industry and Information Technology[2], in 2016, China's textile fiber processing volume reached 54.2 million tons, accounting for more than 50 percent of the global total fiber processing, resulting in a large amount of textile waste. The traditional method of textile waste treatment is landfill treatment or incineration treatment, but landfill treatment requires a large number of sites. Because textile waste, containing a large number of chemical fiber, can't be naturally degraded, and incineration processes produce large amounts of smoke and toxic gases. According to the research data at home and abroad, the majority of textile wastes are non-degradable polypropylene and polyester fibers, with the characteristics of light weight, good tensile resistance and good acid and alkali resistance, etc[3].

In order to reduce the waste of resources, improve the reuse of recycled resources, reduce environmental pollution and reduce the cost of structural members, this paper takes recycled concrete beams as the model. And finite element simulation is used to analyze the effect of different total blending ratio of waste polypropylene fiber and polyacrylonitrile fiber on deflection and inferior of

recycled concrete beam under initial cracking and yield state. The technical reference is provided for the application of waste fiber recycled concrete beam in practical engineering.

2. Conceptual design

In this paper, six groups of hybrid fiber recycled concrete beams are designed. The recycled concrete (RC_0)was prepared by replacing some natural coarse aggregate with 30% (Percentage of gross aggregate mass)recycled aggregate of waste concrete in ordinary concrete(NC_0). In order to improve the properties of recycled concrete, four levels of varying hybrid fiber content in RC_0 group concrete are studied, and the effect of hybrid fiber ratio on crack resistance of recycled concrete beams is analyzed by finite element simulation. In this paper, the length of all beams is set to 1500mm, the net span is 1200mm, and the cross section size of the beam is 120mm × 180mm. The tensile steel bars in the beam are 2B14(HRB335). The steel bar is 2B8(HRB335) and the stirrups are Φ8@100(HPB300). Section size and reinforcement diagram of beam are shown in Fig.1. The test parameters in this paper are shown in Tab.1, and the structural diagram of the beam specimen is shown in fig.1.

Tab.1 The test parameters

test number	aggregate（Kg/m^3）		fiber（Kg/m^3）		compression strength/MPa	split tensile strength/MPa	modulus of elasticity/MPa
	natural aggregate	Recycled aggregate	Waste polypropy-lene fiber	acrylic fibre			
NC_0	990	0	-	-	51.5	3.96	33014
RC_0	693	297	-	-	41.6	3.68	26738
RC_{05}	693	297	0.38	0.15	44.1	3.96	28195
RC_{10}	693	297	0.75	0.29	46.1	4.59	26503
RC_{15}	693	297	1.13	0.44	45.0	3.17	32751
RC_{20}	693	297	1.51	0.59	51.2	4.87	34272

note：RCX represents recycled concrete
The subscript x is a universal ratio of fiber admixture

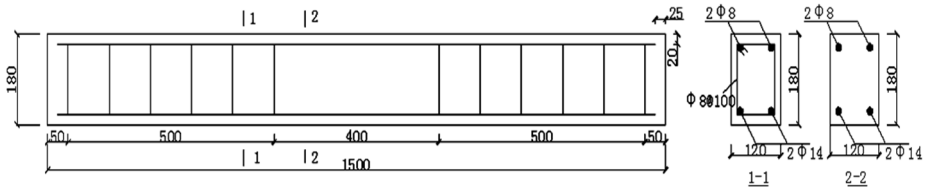


Fig.1 The structure diagram of the specimen（unit：mm）

3. The Establishment of finite element Model

Because there are great differences in mechanical properties between concrete and steel bar, the reinforcement and concrete are solved separately according to different element definitions, that is, separate simulation method. This method makes the simulation process accord with the actual force situation with a high degree. The accuracy of simulation results is high[4]. Therefore, the solid 65 element is adopted for the nonuniform material with the tensile strength of concrete far less than the compressive strength. The link 180 unit is used for the longitudinal tensile steel, the stand ribs and the stirrup. In order to prevent stress concentration, 50mm × 120mm rigid cushion is simulated at the bottom of concrete beam to impose surface constraint on the beam, and 50mm × 120mm rigid cushion is simulated at the three-point loading point to impose surface load on the beam.

In the finite element simulation analysis, the bilinear follower model（BKIN） is used in the steel bar in the beam, and using the Von Mises yield criterion. The finite element software can be used to calculate the nonlinear problem of reinforced concrete. It is easy to converge before cracking. After

cracking, it becomes more and more difficult to converge with the increase of load, and it is subjected to the density of mesh and when the hybrid fiber content is 0.15%, The reinforcing effect of fiber is the most obvious., the number of sub-steps , Convergence Criterion and Convergence Precision[5]. Therefore, in the parameter design, the shear transfer coefficient of open crack is 0.5, the shear transfer coefficient of closed crack is 0.95, the uniaxial compressive strength is -1, that is, the function of crushing is closed. The number of iterations per load step in the solution control is 60, and the output frequency is write every substep. In the nolinear option, the maximum number of cycles is set to 20. The displacement convergence criterion is adopted and the convergence accuracy is 1.5%.

4. Finite element simulation results and analysis

4.1 Simulation analysis of hybrid fiber reinforced recycled concrete beams under initial cracking condition

4.1.1 Initial cracking load of hybrid fiber recycled concrete beam

Fig. 2 is the crack load diagram of the concrete beam. As can be seen from the diagram, compared with the NC_0 beam without recycled aggregate, the cracking load of the RC_0 beam with recycled aggregate is obviously reduced, mainly due to the cracks in the recycled aggregate itself. When mixed with hybrid fiber, the cracking load of concrete beam is higher than that of RC_0 beam, mainly because the hybrid fiber increase the cracking load of concrete beam, delay the development of crack, and enhance the initial crack of beam. The initial cracking load of RC_5, RC_{10}, RC_{15}, RC_{20} beam is increased by 4.2%, 6.4%, 9.5%and 8.8% than the RC_{15} group, respectively, and the effect is the most obvious in the RC_{15} group.

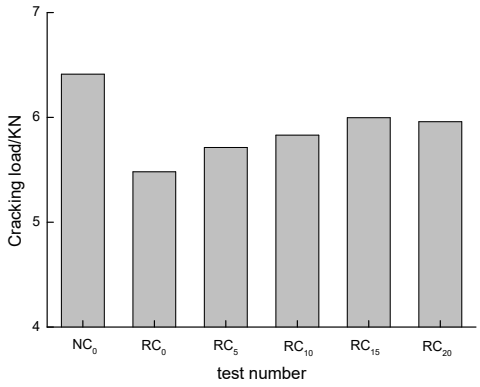


Fig.2 Cracking load diagram of concrete beams

4.1.2 Midspan deflection of hybrid fiber regenerated concrete beams under initial cracking

Fig. 3 shows the mid-span deflection of hybrid fiber regenerated concrete beams under cracking condition. It can be seen from the diagram that the midspan deflection of RC_0 of recycled concrete beams is slightly larger than that of NC_0 beams, mainly because the mixing of recycled aggregate reduces the performance of concrete. However, the mixing of hybrid fibers reduces the mid-span deflection of concrete beams, and the mid-span deflection basically decreases with the increase of the total fiber content, and the deflection of RC_{15} group is the most significant. The main reason is that the stress of the steel bar in the concrete beam is mainly supported by the longitudinal tensile steel before the yield strength is reached, so the mixing of the hybrid fiber has little effect on the deflection value.

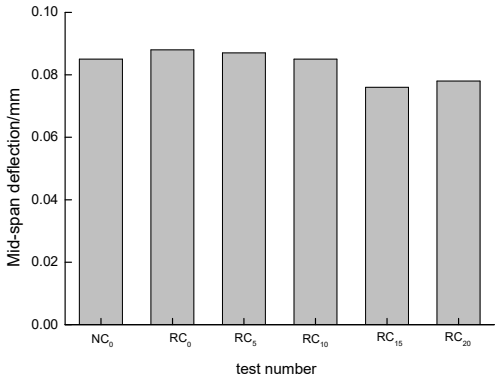
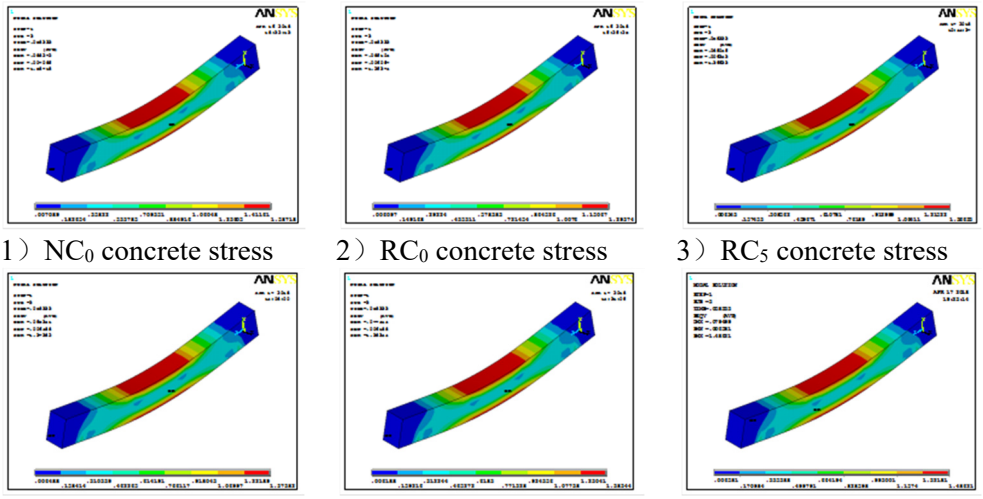


Fig.3 the mid-span deflection of concrete beams under cracking condition

4.1.3 Equivalent crack stress cloud map

Fig. 4 shows the concrete stress cloud diagram of recycled concrete beam with different mixing ratio of hybrid fiber during cracking. It can be seen from the diagram that in the initial cracking state the maximum compressive stress of concrete in recycled concrete beams appears on the upper surface of the span and the maximum tensile stress on the lower surface of the span.



1）NC_0 concrete stress 2）RC_0 concrete stress 3）RC_5 concrete stress

4）RC_{10} concrete stress 5）RC_{15} concrete stress 6）RC_{20} concrete stress

Fig.4 Stress Cloud Picture of concrete under initial cracking condition

4.2 Analysis of simulation results of hybrid fiber regenerated concrete beams under yield state

4.2.1 Yield load of hybrid fiber regenerated concrete beam

Fig. 5 shows the yield load of concrete beam. It can be seen from the diagram that recycled aggregate can reduce the yield load of concrete beam, and RC_0 decreases by 4.13% compared with NC_0. The yield load of concrete beams is enhanced in varying degrees after mixed fibers are added. The yield loads of RC_5, RC_{10}, RC_{15} and RC_{20} beams are increased by 1.44%, 2.32%, 4.63%, 5.06%., respectively, compared with the RC_0 group. This is because the random distribution of hybrid fibers in recycled concrete forms a similar effect to steel bars, absorbs part of the energy, shares the internal stress, and

effectively prevents the generation and development of cracks[6-7]. Therefore, the mixing of hybrid fibers contributes to the cracking of concrete beams.

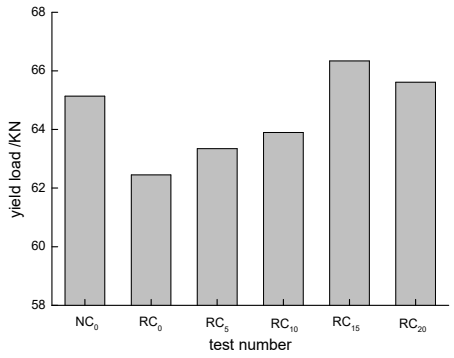


Fig.5 Yield load diagram of concrete beam

4.2.2 Midspan deflection of hybrid fiber recycled concrete beams under yield condition
Fig. 6 shows the mid-span deflection of hybrid fiber reinforced recycled concrete beams under yield condition. It can be seen from the diagram that the mid-span deflection of NC_0 beam is larger than that of RC_0 group beam, but the mid-span deflection of concrete beam decreases with the blending of hybrid fiber, and the deflection of span center is the smallest when the total blending ratio is 0.15%. However, when the total ratio is 0.2%, the deflection of the span increases sharply. Mainly because the large amount of fibers lead to the impact of the concrete properties due to the presence of agglomerations, bond and dispersion in the concrete matrix.

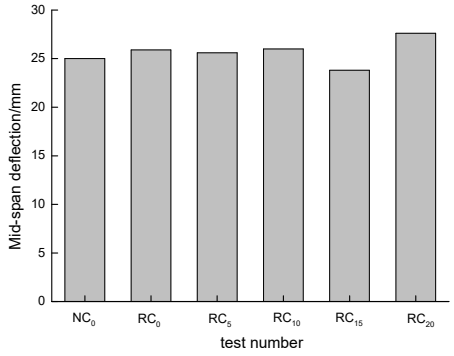
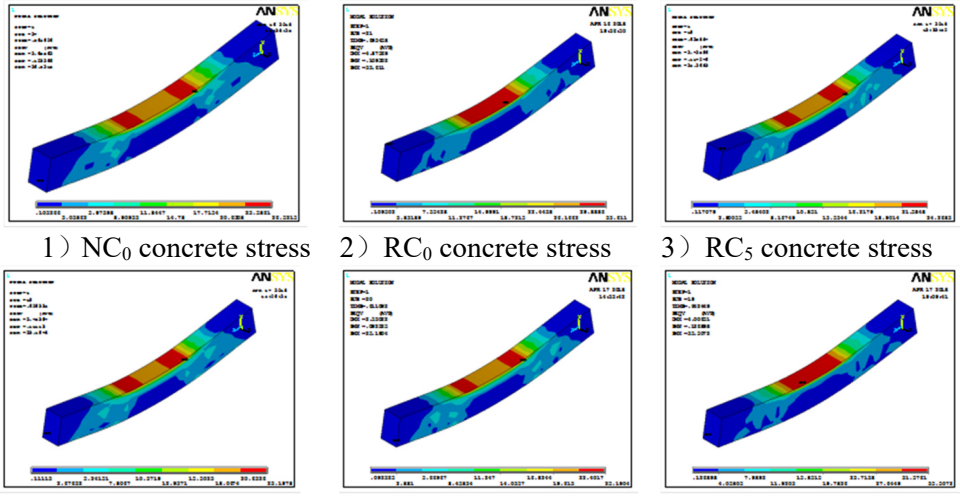


Fig.6 Deflection of concrete beams during cracking

4.2.3 Equivalent yield stress cloud map
Fig. 7 shows the concrete stress cloud diagram of recycled concrete beams under different mixing ratio of hybrid fibers when they yield. It can be seen from the diagram that when the concrete beam is close

to yield, the longitudinal tensile reinforcement almost reaches the yield strength value, and the concrete stress is close to the compressive strength value. And the maximum compressive stress in concrete beam occurs in the compression zone of the middle and upper part of the beam span. The main reason is that the load is borne by concrete after the longitudinal tensile steel bar in the beam with appropriate reinforcement is yield, and the stress of concrete in the compression zone will increase rapidly until the failure.



1）NC_0 concrete stress 2）RC_0 concrete stress 3）RC_5 concrete stress

4）RC_{10} concrete stress 5）RC_{15} concrete stress 6）RC_{20} concrete stress

Fig.7 Stress Cloud Picture of concrete under yield condition

5. Conclusions

In this paper, the influence of the total content of hybrid fiber on the crack resistance of recycled concrete beams is studied by finite element analysis. The conclusions are as follows:

1) The recycled aggregate reduces the cracking load and yield load of concrete beam, but the mixed fiber admixture increases the cracking load and yield load of recycled concrete beam to different extent, and when the hybrid fiber content is 0.15%, the reinforcing effect of fiber is the most obvious.

2) The mid-span deflection of concrete beams decreases with the increase of hybrid fiber content, which indicates that hybrid fibers contribute positively to the crack resistance of recycled concrete beams.

3) Through finite element simulation analysis, it is found that the maximum compressive stress of concrete appears in the middle part of the upper surface span when the initial crack and yield occur, which is consistent with the actual stress situation of the test.

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