Influence of Parent Concrete Strength on the Performance of Recycled Aggregate

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Abstract. In order to explore the difference in the performance of recycled aggregate produced by different strength of parent concrete, six groups of test blocks with different compressive strength were used as parent concrete to prepare recycled aggregate, and relevant experimental analysis was carried out. The test results show that the higher the strength of the parent concrete, the higher the content of needle and flake in the recycled aggregate, and when the strength is greater than 40, the aggregate gradation does not meet the requirements of the specification ; The water absorption rate of recycled aggregate increases first and then decreases with the increase of the strength of parent concrete (C25 ~ C55); The strength of the parent concrete increases, and the crushing value of the recycled aggregate decreases.

Keywords: Parent Concrete; Recycled Aggregate; Needle, Flake Content; Water Absorption Rate; Crushing Value

1 Introduction

With the rapid development of urbanization, there are more and more new construction and expansion projects in the construction field, and the demand for readymixed concrete has increased significantly. Because concrete contains a large number of coarse and fine aggregates, the use of a large amount of concrete will seriously reduce the content of natural resources such as natural sand and gravel, affecting the sustainable development of society. On the other hand, many solid wastes are produced in the new construction, expansion and demolition projects. The comprehensive utilization rate of these solid wastes is low, which seriously pollutes the environment[1,2]. Therefore, the effective use of construction solid waste instead of concrete aggregate can not only save a lot of natural aggregate, but also solve the problem of environmental pollution caused by construction solid waste[3,4].

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In recent years, many scholars have conducted extensive research on the feasibility of using recycled aggregate produced by waste concrete to prepare recycled concrete. Studies have shown that different strength of waste concrete affects the quality of recycled aggregate, and then has a significant impact on the performance of recycled concrete[5,6]. However, the influence of parent concrete on the performance of recycled aggregate is still controversial[7]. Therefore, this paper takes the strength of the matrix concrete as the starting point, and divides the matrix concrete test block into six groups of C25, C30, C35, C40, C50 and C55 according to the actual compressive strength and crushes them with a hammer crusher respectively. Then the related properties of the six groups of recycled aggregates were tested to explore the influence of different original concrete strength on the performance of recycled aggregates, and compared with the existing research conclusions, in order to promote the efficient use of recycled aggregates and provide reference for the future research of recycled concrete.

2 Materials and Test Contents

2.1 Raw Material

According to the existing laboratory conditions and test block reserves, this test first classifies the test blocks according to the actual compressive strength, and di-vides them into six groups: C25, C30, C35, C40, C50 and C55.Then, the hammer crusher is used to crush and classify the bags for subsequent tests. The test reference specifications are ' recycled coarse aggregate for concrete ' GB / T 25177-2010 and ' pebbles and gravels for construction ' GB / T 14685-2022. The preparation of raw materials is shown in Fig. 1.

Fig. 1. Aggregate crushing and packaging.

2.2 Aggregate Screening

The screening test was carried out using a square-hole test sieve with a pore size of 4.75 mm, 9.50 mm, 16.0 mm, 19.0 mm, and 26.5 mm. Firstly, the test sieve is combined into a complete set of sieves from top to bottom according to the pore size, and the sieve is shaken on the shaker, and then the secondary shaker is carried out manually. The 26.5

mm sieve residual aggregate and large flake particles were broken twice by hammer, and the sieve residual quality of each sieve was weighed again, and the bags were classified. The secondary crushing and screening process is shown in Figure 2.

Fig. 2. Aggregates secondary crushing and shaking sieve.

2.3 Content of Needle and Flake Particles

According to the quality requirements of recycled coarse aggregate gradation and needle and flake particle content test, the coarse aggregate obtained by crushing is adjusted according to the gradation specified in the specification. According to the hole width or spacing of different gauges corresponding to different particle size ranges, the aggregate is tested one by one by using the needle gauge and the sheet gauge, and the total mass of the tested needle and sheet particles is weighed. The test is shown in Fig. 3.

Fig. 3. Inspection of needles and flake particles.

2.4 Water Absorption

The needle and flake particle content test was used to carry out the water absorption test of the aggregate after grading adjustment, and the washed aggregate was placed in the barrel. Add water to about 5mm above the water surface, take out after soaking for 24h, use a wet towel to dry the moisture on the surface of the particles, measure the mass of the aggregate at this time, place the aggregate in an oven, and dry it at (105 ± 5) °C. The aggregate water absorption test is shown in Fig. 4.

Fig. 4. Aggregate water absorption test (left is saturated surface dry state, right is after drying).

2.5 Crush Value

According to the requirements of the specification, the aggregate with a particle size of 9.5mm ~ 19.0mm was taken for the test. The sample was divided into two layers and loaded into a circular mold. After each layer was loaded, the left and right sides were inverted. After the two layers were inverted, the flat surface was covered with an indenter and placed on a pressure test machine. Loading to 200kN at a speed of 1kN / s and stabilizing for 5s, then unloading and taking out the sample to weigh its mass, using a 2.36mm square hole test sieve to remove fine particles and weigh the mass left on the sieve. The aggregate crushing value test is shown in Fig. 5.

Fig. 5. Crushing value test.

3 Experiment Results and Analysis

3.1 Aggregate Appearance and Needle (Flake) Particle Content

By observing the broken aggregate, it is found that the recycled coarse aggregate contains more needle and flake particles, and the surface edges and corners of the aggregate are sharper. This phenomenon is more obvious with the increase of the strength of the original concrete of the recycled coarse aggregate, which is improved after the screening of the aggregate. The analysis is because the aggregates collide with each other during the screening process, and some sharp edges and corners are destroyed.

It can be seen from Fig.6 that the content of needle and flake particles C40 ~ C55 is greater than that of C25 ~ C35, but the gap is limited, only 1 % ~ 6 %. M. Chakradhara Rao[8] research reference IS : 383 (1970) C20, C25, C30, C40 obtained by crushing the recycled aggregate sheet content were 18.67 %, 19.6 %, 21.88 %, 22.30 %, the same gap is small and higher strength of the original concrete strength obtained higher.

The increase of needle and flake particles in aggregate has an adverse effect on the strength, elastic modulus and working performance of concrete. Therefore, in order to ensure that the performance of recycled concrete meets the requirements of use, it is necessary to avoid selecting high-strength original concrete to prepare recycled aggregate.

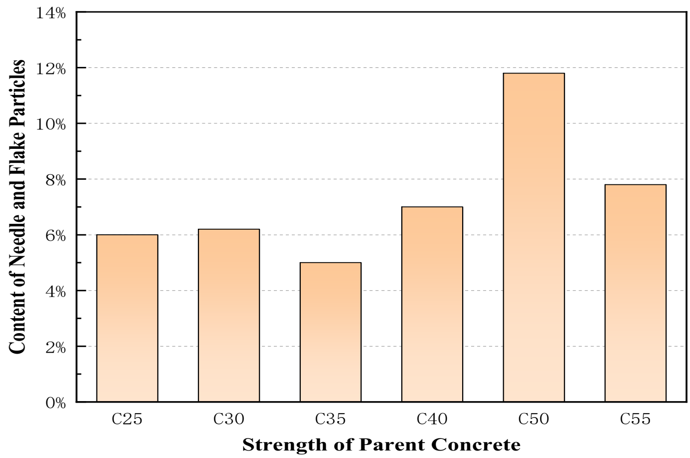

Fig. 6. Content of needle and flake particles.

3.2 Aggregate Gradation

The screening results of recycled aggregates are shown in Table. 1. From the crushing and screening results, it can be seen that the grading of recycled aggregates with parent strength of C25 and C35 meets the specification requirements, while C40 and above do not meet the requirements, and the screen residue of 19.0mm does not meet the requirements.

Analysis shows that due to the distance between the crushing hammer and the lower sieve in the hammer crusher, particles larger than the spacing can be crushed by the hammer, while aggregates with a particle size smaller than the spacing are more likely to be crushed by collisions between the aggregates. The higher the parent concrete strength, the stronger the bond between the mortar and the aggregate in the concrete, and the smaller the particle size during the collision process. Therefore, the higher the parent strength of the concrete, the higher the content of large particle size aggregates produced after crushing.

In order to make the recycled aggregate gradation meet the requirements, we should try to avoid using the original concrete with higher strength for crushing or using the crusher with higher power and better crushing process for crushing.

Table 1. Recycled aggregate screening results.

size of screen mesh /mm	Standard cumulative sieve residue /%	Cumulative sieve residue of recycled aggregate /%					
		C25	C30	C35	C40	C50	C55
19	0~10	7.90%	16.70%	9.70%	20.10%	18.60%	21.70%
16	—	35.60%	30.60%	21.60%	31.40%	29.80%	36.60%
9.5	40~80	62.90%	67.40%	60.50%	67.10%	65.00%	71.70%
4.75	90~100	97.90%	99.00%	97.80%	97.40%	98.20%	97.90%
2.36	95~100	98.90%	99.50%	98.90%	98.70%	99.10%	99.00%

3.3 Water Absorption

The Fig.7 shows the test results of water absorption of recycled aggregate. According to the technical specification for the utilization of construction waste in highway engineering (JTGT 2321-2021), the water absorption of recycled coarse aggregate should not be greater than 8.0 %, and the aggregate obtained from the test can meet the requirements of the specification.

The results of Fig.7 show that the water absorption of C25 ~ C35 increases gradually, but the gap is only about 1 %, which is the same as the research results of M.Chakradhara Rao [9].In other words, the higher the strength of the parent concrete, the higher the water absorption of the recycled aggregate. There is no significant difference between the C50 group and the C35 group, but there are many differences between the C50 group and the C40 and C55 groups. The water absorption of C40 and C55 is lower than that of C25 ~ C35, which is consistent with the results of Jingwei Ying[10] and Kaihua Liu [11], that is, the higher the strength of the parent concrete, the lower the water absorption of recycled aggregate. The residual old mortar in the recycled coarse aggregate is more porous than the aggregate. The higher the strength of the parent concrete is, the lower the water-cement ratio is. The mortar in the concrete contains fewer pores, and the residual old mortar corresponding to the recycled coarse aggregate has fewer pores and lower water absorption.

The strength of parent concrete in the study of Chakradhara Rao is low, which is C20 ~ C40. The strength of parent concrete in the study of Jingwei Ying and Kaihua Liu is high, which is C35 ~ C60. The strength samples of parent concrete in this paper are more extensive, which are C25 ~ C55. The analysis shows that when the strength of the original concrete is low, the content of the mortar attached to the surface of the recycled aggregate plays a major role in controlling the water absorption, that is, the higher the strength of the original concrete, the more the content of the mortar attached to the recycled aggregate, the greater the water absorption. When the strength of the original concrete is high, the quality of the mortar attached to the surface of the recycled aggregate plays a major role in controlling the water absorption rate, that is, the higher the strength of the original concrete, the higher the quality of the adhesive mortar of the recycled aggregate, and the lower the water absorption rate of the recycled aggregate.

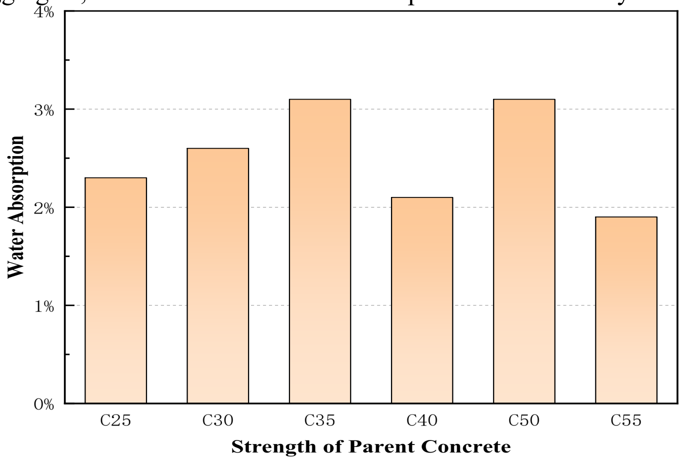

Fig. 7. Recycled aggregate water absorption rate.

3.4 Crush Value

It can be seen from the results of Fig.8 that the minimum crushing value of the test was 13 % in the C50 group and the maximum was 17 % in the C25 group. The crushing value of recycled aggregate obtained from the test is below 18 %. According to the standard classification, they all belong to class I recycled coarse aggregate. Because the C55 group test aggregate is only 1.37 kg, there is a big gap with the standard requirement of about 3 kg, the error of the test data is not considered.

From C25 to C50, the crushing value of recycled aggregate decreases with the increase of the strength of the original concrete, which is consistent with the research results of A.K.Padmini[12]. The higher the strength of the original concrete corresponding to the recycled coarse aggregate, the higher the bonding strength of the old mortar attached to the natural aggregate, the more difficult the crushing value of the recycled coarse aggregate is to be broken, and the crushing value is reduced. The crushing value of recycled aggregate prepared by the waste test block in the laboratory meets the requirements of the specification, and can be further used to prepare recycled concrete to study the relationship between the strength of recycled concrete and the original concrete.

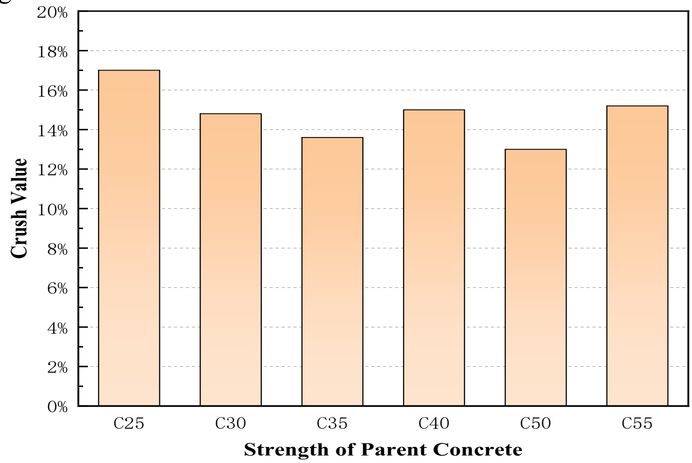

Fig. 8. Recycled aggregate crushing value.

4 Conclusion

This paper explores the influence of the strength of parent concrete on the performance of recycled aggregate. The conclusions are as follows:

(1) With the increase of the strength of the original concrete, the content of the needle and flake particles of the recycled aggregate increases, and the edges and corners of the aggregate surface are sharp. When the strength is greater than 40, the aggregate gradation does not meet the requirements of the specification, and the sieve margin of the 19.0mm sieve is larger. The parent concrete with higher crushing strength should be avoided as the aggregate of recycled concrete to ensure the reasonable aggregate gradation.

(2) The water absorption rate of recycled aggregate increases first and then decreases with the increase of the strength of parent concrete (C25 ~ C55). When the strength of the original concrete is low, the content of the mortar attached to the surface of the recycled aggregate plays a major role in controlling the water absorption. When the strength of the original concrete is high, the quality of the mortar attached to the surface of the recycled aggregate plays a major role in controlling the water absorption.

(3) The higher the strength of the parent concrete, the higher the bonding strength of the old mortar attached to the natural aggregate, and the lower the crushing value.

In this paper, the waste test block in the laboratory is used as the parent concrete, and the related properties of the recycled aggregate are tested. The source of the recycled aggregate and the feasibility of replacing the original aggregate are studied. In order to obtain better particle gradation, a crusher with higher power or better crushing process can be considered. In addition, the performance of the recycled aggregate obtained by crushing the waste test block in the laboratory conforms to the relevant specifications, which can be further used to prepare recycled concrete to explore the influence of the parent concrete on the performance of recycled concrete.

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