International Journal of Latest Research in Humanities and Social Science (IJLRHSS)
Volume 04 - Issue 11, 2021
www.ijlrhss.com || PP. 83-88

Comparative study on physical properties of common and high performance recycled coarse aggregate

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Abstract: Starting from the preparation process of reclaimed coarse aggregate, the physical properties of ordinary reclaimed coarse aggregate and high-performance reclaimed coarse aggregate, such as surface shape, gradation, density, voidage, water absorption, firmness, crushing index, mud content and so on, are compared and analyzed in this paper. Finally, the conclusions of the comparative study are given.

Keywords: Ordinary recycled coarse aggregate; High performance recycled coarse aggregate; Physical properties; The comparative study

1. The production process of recycled coarse aggregate

1.1 The process of preparing ordinary recycled coarse aggregate by traditional process

At present, there are many technological processes for the production of recycled coarse aggregate concrete in China. These technological processes can be roughly summarized as manual or mechanical sorting, initial crushing, sorting and crushing again, and finally screening out the recycled coarse aggregate needed. The properties of the recycled aggregate produced by these production processes are general, and the mechanical properties of the recycled concrete prepared are obviously different from those of ordinary concrete (matrix concrete). In order to verify the existing research results on the mechanical properties of recycled concrete at home and abroad, and in order to make a comparison with high-performance recycled concrete, this topic designed the mechanical properties of ordinary recycled aggregate concrete prepared by traditional technology. The production process of recycled coarse aggregate is designed according to the most common scheme in China.

1.2 Preparation process of high performance recycled coarse aggregate

With reference to Shima recycled aggregate production process and wet treatment process, and considering the current social and economic background in China, a high performance recycled coarse aggregate production process was designed. Compared with the common coarse aggregate production process, it is found that this production process increases mechanical wear and water washing two processes. The purpose of increasing mechanical wear process is to remove the old cement mortar adhered to the surface of reclaimed coarse aggregate and the prominent edges and corners of aggregate. The purpose of adding water washing process is to eliminate the small impurities such as soil and cement powder doped in the reclaimed aggregate, so as to ensure the high performance of coarse aggregate. Through the later test, it is found that adding these two processes can indeed improve the performance of recycled aggregate, and recycled coarse aggregate concrete with superior performance can be produced.

2. Comparative study on physical properties of ordinary and high-performance recycled coarse aggregate

The physical properties such as gradation, density, moisture content, firmness and mud content of natural coarse aggregate (NA), ordinary recycled coarse aggregate (RA) produced by traditional process and high-performance recycled coarse aggregate (HRA) produced by improved process were compared and studied. The factors affecting the physical properties of reclaimed coarse aggregate were analyzed through experimental comparative study, so as to provide theoretical reference for improving the physical properties of reclaimed coarse aggregate.

2.1 Surface shape of reclaimed coarse aggregate

The surface shape of ordinary recycled coarse aggregate processed by traditional technology is irregular, and it can be seen that there are relatively prominent sharp edges and corners. Moreover, due to the defects of the processing technology, a lot of old cement mortar is attached to the surface of coarse aggregate, and at the same time, the coarse aggregate is obviously doped with wood chips, soil and other impurities. The physical performance of high-performance recycled coarse aggregate produced by adding mechanical grinding and water washing has been significantly improved, which is embodied in: the surface shape of recycled coarse aggregate is more regular than that of ordinary recycled coarse aggregate, and there are almost no prominent sharp edges and corners; The old cement mortar originally attached to the surface of reclaimed coarse aggregate has been greatly reduced, and the impurities contained in it have been greatly reduced. Through these obvious surface changes, it can be found that adding mechanical grinding and water washing can indeed improve the surface shape of coarse aggregate, thus creating conditions for improving the physical properties of recycled coarse aggregate and obtaining high performance recycled concrete.

2.2 Study on gradation of coarse aggregate

Whether the performance of coarse aggregate can be fully developed depends largely on its gradation. Through the experimental study, it is found that the particle size of recycled coarse aggregate is smaller than that of natural coarse aggregate on the whole, and the gradation difference between ordinary recycled coarse aggregate and high-performance recycled coarse aggregate is not obvious, as shown in Table 1 below. Analysis its reason, this paper argues that due to the processing of recycled coarse aggregate through crushing, crushing and grinding process, these have larger external force in the process, these external force waste concrete by whole become zero at the same time, also can make some of the original natural coarse aggregate in waste concrete split and broken, making of recycled coarse aggregate particle size smaller than natural coarse aggregate as a whole. However, the gradation of ordinary recycled coarse aggregate and high-performance recycled coarse aggregate is basically the same, and the analysis of the reason may be that roughly the same original natural coarse aggregate is stripped out in the processing process, but the surface of high-performance coarse aggregate is neat and clean.

Table 1 Study on grade matching ratio of coarse aggregate

Cumulative screen allowance	31.5mm（%）	20.0mm（%）	10.0mm（%）	5.0mm (%)
Natural coarse aggregate	3.6	26.5	77.9	97.6
General recycled coarse aggregate	2.3	21.3	71.5	91.2
High performance recycled coarse aggregate	1.7	22.4	72.8	94.9
The specification requires	0～5	15～45	70～90	90～100

2.3 Density and voidage of coarse aggregate

After testing, the apparent density and loose bulk density of aggregate are shown in Table 2.

Table 2 Aggregate apparent density and loose bulk density

The name of the aggregate	Grain size（mm）	The apparent density（kg/ m3）	Loose packing density（kg/ m3）
General recycled coarse aggregate	5~31.5	2476	1288
High performance recycled coarse aggregate	5~31.5	2649	1392
Natural coarse aggregate	5~31.5	2797	1459

Test data analysis, the author found out that ordinary the apparent density of recycled coarse aggregate and loose packing density are about 10% smaller than natural coarse aggregate, analyze the causes, and may be a common recycled coarse aggregate surface not neat, but also adhere to the number of many of the old cement mortar, so lead to the accumulation of ordinary recycled concrete is loose, which affects its density. The density of high performance reclaimed coarse aggregate was found to be significantly higher than that of ordinary reclaimed coarse aggregate, and the gap between reclaimed coarse aggregate and natural coarse aggregate was reduced to about 5%. The reason for this phenomenon may be that mechanical grinding and water washing processes lead to a more orderly surface of the recycled aggregate, and also effectively remove the old cement mortar and impurities from the aggregate surface, making it more dense and closer to the natural aggregate

Through simple mathematical operations, the voidage of coarse aggregate is shown in Table 3 below.

Table 3 Void ratio of coarse aggregate

The name of the aggregate	General recycled coarse aggregate	High performance recycled coarse aggregate	Natural coarse aggregate
Void fraction（%）	47.98	47.45	47.84

2.4 Water absorption of coarse aggregate

After testing, the water absorption of aggregate is shown in Table 4 below.

Table 4 Water absorption of coarse aggregate

The name of the aggregate	Grain size（mm）	30min ω_{wa} (%)	24h ω_{wa} （%）
General recycled coarse aggregate	5~31.5	6.25	6.45
High performance recycled coarse aggregate	5~31.5	1.86	1.98
Natural coarse aggregate	5~31.5	0.71	0.76

Through the comparative analysis of test data, it is found that the water absorption rate of reclaimed coarse aggregate is much greater than that of natural aggregate, and the performance of ordinary reclaimed coarse aggregate is extremely outstanding, and its water absorption rate is about 10 times that of natural coarse

aggregate. By analyzing the reasons, it is considered that the recycled coarse aggregate is produced by crushing, rolling, grinding and other production processes of waste concrete, and its surface is inevitably attached with old cement mortar, and the water absorption rate of cement mortar is much higher than that of natural coarse aggregate. At the same time, due to the action of external forces in the production process, it is inevitable to cause damage in the recycled coarse aggregate, resulting in the increase of cracks and pores, and the final performance is that the water absorption rate of the recycled coarse aggregate is significantly greater than that of the natural coarse aggregate.

By comparing the high performance coarse aggregate with the common reclaimed coarse aggregate, it is found that the water absorption of the common reclaimed coarse aggregate is about 3 times that of the high performance reclaimed coarse aggregate. The reason for this phenomenon may be that the waste cement mortar and prominent sharp edges on the surface of recycled coarse aggregate are effectively removed by improving the production process of recycled coarse aggregate, thus reducing the water absorption rate of high-performance recycled coarse aggregate.

2.5 Ruggedness and crushing index of coarse aggregate

The ruggedness of coarse aggregate was tested as shown in Table 5 below.

Table 5 Test results of robustness of coarse aggregate

The name of the aggregate	General recycled coarse aggregate	High performance recycled coarse aggregate	Natural coarse aggregate
Total mass loss rate（%）	8.31	5.77	4.15

By comparing the experimental data, it is found that the total mass loss of reclaimed coarse aggregate is significantly greater than that of natural coarse aggregate, and the firmness index of ordinary reclaimed coarse aggregate is twice that of natural aggregate. This shows that in the process of processing and production of waste concrete, under the action of external forces, the internal damage of reclaimed coarse aggregate occurs, thus affecting the solidity of reclaimed coarse aggregate. However, the solidity of high-performance reclaimed coarse aggregate is better than that of ordinary reclaimed coarse aggregate, which may be due to the fact that the amount of old cement mortar adhered to the surface of high-performance reclaimed coarse aggregate is less, leading to a significantly smaller mass loss in the test.

After testing, the crushing index percentage of coarse aggregate is shown in Table 6.

Table 6 Crushing index percentage of coarse aggregate

The name of the aggregate	General recycled coarse aggregate	High performance recycled coarse aggregate	Natural coarse aggregate
Crush indicators（%）	16.73	10.47	4.55

Through the comparative study of experimental data, it can be found that the crushing index of reclaimed coarse aggregate is about 3 times that of natural coarse aggregate, and the crushing index of ordinary reclaimed coarse aggregate is significantly higher than that of high-performance reclaimed coarse aggregate. The reason for this result is that the processing process leads to different degrees of damage in the recycled coarse aggregate. The fine cracks in the recycled coarse aggregate play a great role in the crushing test, leading to the crushing index of the recycled coarse aggregate is significantly higher than that of the natural coarse aggregate. However,

with the decrease of the amount of old cement mortar on the surface of high performance reclaimed coarse aggregate, the crushing index value of reclaimed coarse aggregate is obviously lower than that of ordinary reclaimed coarse aggregate.

2.6 Mud content of coarse aggregate

The content of soil, wood chips, scrap metal and other impurities in aggregate will also affect the performance of concrete to a large extent, so this topic design of coarse aggregate mud content test. The purpose is to verify whether adding water washing process can effectively reduce the content of soil and other impurities in reclaimed coarse aggregate.

According to the test, the percentage of mud content of coarse aggregate is shown in Table 7.

Table 7 Percentage of mud content of coarse aggregate

The name of the aggregate	General recycled coarse aggregate	High performance recycled coarse aggregate	Natural coarse aggregate
Silt content（%）	3.71	0.85	0.87

According to the observation data, the mud content of high-performance recycled coarse aggregate is the lowest among the three kinds of coarse aggregate, which should benefit from the water washing process, which separates a lot of dirt, old cement mortar powder, wood chips and other impurities from the coarse aggregate, which also creates favorable conditions for the preparation of high-performance recycled concrete.

3. Conclusion

3.1 The gradation of ordinary recycled coarse aggregate and high performance recycled coarse aggregate is basically the same; The apparent density and loose bulk density of the common reclaimed coarse aggregate were about 10% smaller than that of the natural coarse aggregate, while the difference between the density of the high performance reclaimed coarse aggregate and the natural coarse aggregate was about 5%. The water absorption rate of reclaimed coarse aggregate is much greater than that of natural aggregate, and the performance of ordinary reclaimed coarse aggregate is extremely outstanding, and its water absorption rate is about 10 times that of natural coarse aggregate.

3.2 The total mass loss of reclaimed coarse aggregate is significantly greater than that of natural coarse aggregate, the robustness index of ordinary reclaimed coarse aggregate is twice that of natural aggregate, and the robustness of high-performance reclaimed coarse aggregate is close to that of natural coarse aggregate. The crushing index of reclaimed coarse aggregate is about 3 times that of natural coarse aggregate, and the crushing index of ordinary reclaimed coarse aggregate is obviously higher than that of high performance reclaimed coarse aggregate.

3.3 The mud content of high-performance recycled coarse aggregate is the lowest among the three coarse aggregates, which should benefit from the water washing process to separate a large amount of dirt, old cement mortar powder and wood chips from the coarse aggregate.

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