Applicability Analysis of Construction Waste Recycled Aggregate in Construction of Sponge City

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Abstract. As the construction of sponge cities in China is in full swing, it is necessary to use a lot of crushed stones and gravels, which will damage the ecological environment. It is imminent to use recycled aggregates to replace natural crushed stones and gravels for sponge city construction. Aiming at the applicability of recycled aggregates in sponge cities, by conducting experimental research on the water absorption, water storage and water permeability characteristics of recycled aggregates, it is concluded that the water absorption and water storage properties of recycled aggregates are better than natural crushed stones and water permeability slightly worse than natural crushed stone, further verifying the applicability of recycled aggregates in the construction of sponge cities, and the prospects for future popularization and application are considerable.

Introduction

Sponge city is a new concept put forward in response to the serious water environment problems in the process of rapid urbanization in China. Building a sponge city with natural accumulation, natural penetration and natural purification is a new measure to protect and improve the urban ecological environment. To build a sponge city, we must not only reduce the city’s waterlogging, but also achieve the goal of "repairing water ecology, conserving water resources, improving water environment, improving water security, and rejuvenating water culture" aims. During the construction of the sponge city, a lot of building materials such as gravel and gravel are used, and these materials need to be obtained by digging mountains and rivers. Under the call of green development and sustainable development, people have realized the importance of protecting the ecological environment. The concept of "Golden and silver mountains are green water and green mountains" has become a social consensus. Can other materials be used instead of natural stone such as gravel or gravel? Recycled aggregate processed from construction waste can be fully realized.

Component Analysis

The main components of construction waste are bricks, concrete blocks and stones, as shown in Figure 1. In order to understand the content of each component in the recycled aggregate, representative 10-20mm and 20-30mm recycled aggregate samples were selected, and they were sorted and weighed manually to calculate the component materials in brick-concrete buildings. Table 1 shows the calculation results of the proportion of waste recycled aggregate.

| classification      | 10-20mm Recycled aggregate | 20-30mm Recycled aggregate |
|---------------------|----------------------------|----------------------------|
| Bricks /%           | 69.8                       | 62.5                       |
| Concrete blocks and stones /% | 27.1                      | 33.0                       |
| Ceramics /%         | 3.1                        | 4.6                        |

The test shows that the proportion of the components of the recycled aggregate from large to small...
is brick> concrete stone> ceramic. Among them, bricks account for the largest proportion, reaching nearly 70%, which is the main component of recycled aggregate. Due to the differences in building structures, foreign construction waste is dominated by concrete, while China's construction waste is mainly brick and concrete, so the content of bricks in processed recycled aggregate is high. The shape of the brick is irregular, there are many edges and corners, the pin-like content is high, the surface is porous, and the dead weight is light. It belongs to a lightweight porous structure. The content is small, the structure of the stone is dense, the content of pore volume is extremely low, and the dead weight is large.

Water Absorption Characteristics Analysis

Test Method

The water absorption rate refers to the ability of the aggregate to absorb water at standard atmospheric pressure, and is expressed by the mass ratio of the absorbed moisture to the aggregate after the dried aggregate absorbs water to saturation. The water absorption is directly related to the internal porosity of the aggregate and the composition of the mixture. The smaller the water absorption, the tighter and harder the aggregate. In order to analyze the effect of the components on the water absorption characteristics of the recycled aggregate, this test uses manual sorting to separate the components of the recycled aggregate and redistribute them according to different proportions. As shown in Figure 1, the matching ratio of bricks and concrete blocks is 10: 0, 9: 1, 8: 2, 7: 3, 6: 4, 5: 5, and the particle size is 5-10mm, 10-20mm and 30-50mm. According to the "Rough Aggregate Density and Water Absorption Test (T 0304-2005) (Net Basket Method)" , a 24-hour water absorption test was carried out on 3 kinds of recycled aggregates with different particle sizes.

![Figure 1](image1.jpg)

Figure 1. Test the water absorption of recycled aggregates with different brick contents.

Test Results and Analysis

Figure 2. shows the results of the water storage coefficient tests for different particle sizes and different types of recycled aggregates.

![Figure 2](image2.jpg)

Figure 2. Water absorption test results of recycled materials with different brick contents.

From the test results, it can be seen that the water absorption rate of the recycled aggregate is high, and the water absorption rate of the recycled aggregate with a particle size of 10-20 mm reaches
17.65%, which is much higher than that of the natural aggregate. The main reason is that 60%-70% of the recycled aggregate composition is bricks and tiles, with a large brick content and a part of the cement mortar attached to the surface, and the two components themselves have low strength and a loose porous structure with large porosity. Therefore, this also directly leads to a higher overall water absorption of the recycled aggregate.

With the increase of the brick content, the water absorption of the mixture also gradually increased. At the same time, laboratory tests have found that the water absorption of natural aggregates is 0.1% at 1h and 24h, and the water absorption capacity is up to 170 times that of natural aggregates, indicating that recycled aggregates have the advantages of high water absorption and good water storage. Water absorption increases with decreasing particle size and surface area. The high water absorption of recycled aggregate is generally considered to be its most important feature compared to natural aggregate. Therefore, from the perspective of water absorption and storage of materials, Recycled aggregate is particularly suitable as a building material for construction of sponge cities.

**Analysis of Water Storage Characteristics**

**Test Method**

The water storage characteristics of the recycled aggregate means that when the recycled aggregate itself absorbs water and becomes saturated, the aggregate gap in the mixture will further contain a portion of water. This experiment studies different types of aggregates (natural and recycled aggregates), different brick contents (50%, 60%, 70%, 80%, 90% and 100%) and different particle sizes (5-10mm, 10-20mm and 30-50mm) the effect of single-grade aggregate on storage coefficient.

As there are no relevant standards available for reference, this test was conducted using the following test methods:

1. After soaking the recycled aggregate in water for 24 hours, after the water in the surface and the internal communication pores have been fully saturated, use a wrung wet towel to gently dry the water on the surface of the particles, that is, the water content in the internal pores of the aggregate reaches its saturated and its surface is still dry. At this time, the natural saturated surface of the aggregate is dry.

2. Put the recycled aggregate with natural saturated surface into the hollowed-out circular utensil at the bottom. In this test, the thickness is 5cm, and the mass of the loaded aggregate is weighed. Spray water on the surface, adjust the water to spray, in order to ensure the uniformity of spraying, when spraying water, the outer edge is clockwise, then the middle, and then cycle. The pores on the surface of the recycled aggregate and the spaces between the aggregates can further store water. When the water storage reaches the maximum level, that is, the saturated state, the water in the connected pores will seep and sink downward under the combined action of gravity and pore water tension. It becomes a water stream, and the moment the water is saturated and infiltrated is the saturated state of storage, and the test is stopped at this time.

3. Calculate the water spray quality and recycled aggregate mass separately. The percentage of water spray quality and recycled aggregate mass is the water storage coefficient.

**Test Results and Analysis**

The water storage coefficient test results of different particle sizes and different types of recycled aggregates are shown in Figure 3. As a comparison test, the water storage coefficients of 5-10mm crushed stone, 10-20mm crushed stone and 30-50mm crushed stone are 3.06%, 4.10% and 2.2%.

It can be known from the test data in Figure 3 that as the particle size of the single aggregate particles increases, the storage coefficient decreases significantly. According to the basic characteristics of aggregates, it can be known that the surface of the recycled aggregate is rough and the specific surface area is large. Therefore, with the same aggregate, the water storage coefficient of the recycled aggregate is significantly better than that of natural aggregate. For aggregates with a water storage layer thickness of 5 cm, when the aggregate particle size increases from 5-10mm to
10-20mm, the storage coefficient of the recycled aggregate decreases by approximately 19.0%, and the storage coefficient of the natural aggregate decreases by approximately 25.4%.

Figure 3. Water storage coefficient of recycled mix with different brick contents.

With the increase of the single particle size, the gap between the aggregates becomes larger, which makes it easier for the water to flow out of the seepage channel, resulting in a decrease in the storage coefficient. However, the decline rate of the natural aggregate water storage coefficient is significantly greater than that of the recycled brick aggregate. From this, it can be concluded that the recycled brick aggregate can not only fully absorb water, but also effectively retain water, and has a good water storage capacity. The material is extremely suitable.

Permeability Analysis

Test Method

Since the normal water head test is suitable for materials with small particle sizes such as fine-grained soil, this test uses 5-10mm, 10-20mm and 30-50mm recycled aggregates with larger particle sizes and larger mixture gaps. During the water head test, the pressure gauge tube failed to form a water level difference, so the asphalt pavement water meter was used to test the water permeability coefficient of the recycled aggregate. The test of the water permeability coefficient of the recycled aggregate is carried out in accordance with the “Test Regulations for Highway Subgrade and Pavement Field Test” (JTG E60-2008). Set a counterweight again and observe the time from the 100ml mark until the water surface drops 500ml.

Test Results and Analysis

The water permeability time of different particle sizes and different types of recycled aggregates is shown in Table 4, and the water permeability coefficient is shown in Figure4. The natural crushed stone results for the comparison test were 9.30s (2580.65ml/min) for 5-10mm crushed stone, 10-20mm crushed stone 9.8s (2448.98ml/min), 30-50mm crushed stone 8.21s (2923.26ml/min).

Table 4. Test result of aggregate seepage time (unit: s).

| Particle size/mm | 50  | 60  | 70  | 80  | 90  | 100 |
|------------------|-----|-----|-----|-----|-----|-----|
| 5-10             | 11.08 | 11.64 | 10.55 | 11.20 | 10.27 | 10.70 |
| 10-20            | 8.75  | 10.20 | 9.90  | 9.13  | 10.02 | 9.36  |
| 30-50            | 9.49  | 10.28 | 10.19 | 9.91  | 9.86  | 9.04  |
The test shows that the 5-10mm recycled aggregate has the smallest water permeability coefficient (the largest storage coefficient), and the 10-20mm recycled aggregate has the same water permeability coefficient as the 30-50mm recycled aggregate, with the highest value reaching 2742.86ml/min. It can be seen from Figure 4 that with the increase of the brick content, the water permeability coefficient of the recycled aggregate mixture does not show obvious regularity. Therefore, we can conclude that there is no direct correlation between the water permeability coefficient and the brick content, that is, the composition of the recycled aggregate has little effect on its water permeability. The water permeability coefficient is mainly related to the particle size and particle shape of the mixture. The permeability coefficient of natural crushed stone is better than that of recycled aggregate in the same grade. The reason is mainly because the particle shape of natural crushed stone is more regular, the composition of the mixture is more uniform, and the highest value of the permeability coefficient is 2923.26ml/min.

Conclusion
Through the analysis of the material characteristics of the recycled aggregate of construction waste, it was found that its water absorption rate and storage coefficient are significantly better than natural aggregates. The excellent water storage performance of the recycled aggregate was confirmed, and its applicability to sponge cities was verified. Provide a reference for the selection of construction waste recycled aggregates in sponge cities. Construction waste will be a good building material after treatment. The use of construction waste recycled aggregate in sponge cities can not only solve the problem of shortage of natural aggregate such as crushed stones, gravel, etc., but also make the best use of it to turn construction waste into treasure, and at the same time reduce the cost of construction. China's requirements for sustainable development and low-carbon environmental protection have broad application scenarios.

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