# Concrete from Construction Solid Waste

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With the development of human society and urban modernization, a large amount of construction waste is generated every year due to the demolition of buildings. The annual output of these construction wastes can reach 4 billion tons, and the output is increasing year by year. Most of these construction wastes are directly dumped or landfilled, and the recycling rate is extremely low; pollution of the environment is increasingly serious. In recent years, with the awakening of human environmental awareness, coupled with natural aggregates and cementing material in short supply, people have gradually turned their attention to this part of construction waste. Various technical means to prepare it into RCA, RFA, and RP, and recycled concrete. However, the performance of these recycled materials is generally inferior to that of natural materials.

Keywords: recycled aggregate ; recycled powder (RP) ; recycled concrete ; performance test ; microstructure ; interface transition zone

## 1. Overview

Solutions are needed to solve the problem of a large amount of construction solid waste and a shortage of natural aggregate (coarse and fine aggregates). In this paper, simple-crushed coarse aggregate (SCRCA) and simple-crushed fine aggregate (SCRFA) were obtained by simple-crushing of construction solid waste. On this basis, SCRCA and SCRFA were treated with particle-shaping to obtain particle-shaping coarse aggregate (PSRCA) and particle-shaping fine aggregate (PSRFA), and the recycled powder (RP) produced in the process of particle-shaping was collected. Under the condition of a 1:4 cement-sand ratio, RP was used to replace cement with four substitution rates of 0, 10%, 20%, and 30%, and dry-mixed masonry mortar was prepared with 100% SCRFA, PSRFA, and river sand (RS). The basic and mechanical properties and microstructure of hydration products of dry-mixed mortar were analyzed, and the maximum substitution rate of RP was determined. Under the condition that the amount of cementitious material is 400 kg/m$^3$ and the RP is at the maximum replacement rate, three different aggregate combinations to prepare concrete are the 100% use of SCRCA and SCRFA, PSRCA and PSRFA, and RS and natural aggregate (NCA); the workability, mechanical properties, and aggregate interface transition zone of the prepared concrete were analyzed. The results show that when the replacement rate of RP is less than 20%, it has little effect on the properties of products. The performance of PSRCA and PSRFA after treatment is better than that of SCRCA and SCRFA. Under different RP substitution rates, the performance of dry-mixed mortar prepared with PSRFA is very close to that prepared with RS. The performance of recycled concrete prepared with PSRCA and PSRFA is also very close to that of products prepared with NCA and RS. The failure morphology of PSRCA and RSRFA concrete is also similar to that of NCA and RS concrete.

## 2. Construction Solid Waste

With the development of human society and urban modernization, a large amount of construction waste is generated every year due to the demolition of buildings. The annual output of these construction wastes can reach 4 billion tons, and the output is increasing year by year [1][2][3][4][5][6]. Most of these construction wastes are directly dumped or landfilled, and the recycling rate is extremely low; pollution of the environment is increasingly serious [7][8][9]. In recent years, with the awakening of human environmental awareness, coupled with natural aggregates and cementing material in short supply, people have gradually turned their attention to this part of construction waste. Various technical means to prepare it into RCA, RFA, and RP, and recycled concrete [10][11][12]. However, the performance of these recycled materials is generally inferior to that of natural materials [13][14][15].

How to effectively use this part of recycled materials to turn waste into treasure has become a hot topic for researchers in many countries and regions in the world. First, some scholars have studied the principle of performance loss of recycled products caused by recycled materials. C. Thomas, S. Pradhan, and R. Wang found that the mortar attached to the recycled aggregate is the main factor affecting the performance degradation of the aggregate, and when the recycled aggregate is prepared as recycled concrete, the mortar adhesion rate of the secondary recycled aggregate recovered from the recycled concrete can be more than twice that of the primary recycled aggregate [16][17][18]. At present, the main use of recycled or treated recycled aggregate is to replace natural aggregate at a certain rate. To ensure the performance of recycled concrete products, a large number of scholars have explored the performance of concrete mixed with recycled aggregate. M. C. Shah used RCA instead of NCA to prepare recycled concrete with a gradient of 7%, 14%, 21%, and 28% and studied the mechanical properties of recycled concrete. It was found that the mechanical properties of recycled concrete could still meet the design requirements [19]. Ruaa Yousif Hassan used RCA to replace NCA at 100%, and RFA to replace RS with 25%, 50%, 75%, and 100% replacement rates to prepare recycled self-compacting concrete with different mix ratios and study its mechanical properties. It was found that the use of RFA instead of RS had little effect on the performance of recycled self-compacting concrete [20]. D. Gao prepared SFRFA by using steel fiber to process RFA, and using RFA and SFRFA to prepare recycled concrete, and explored the mechanical properties of recycled concrete. The results demonstrated that the concrete prepared with SFRFA had a significant performance improvement compared with the concrete prepared with RFA [21]. M. Kaarthik used RFA to replace RS at different substitution rates to prepare recycled concrete. By studying the mechanical properties of recycled concrete, it was found that when the RFA substitution rate was 60%, the strength of recycled concrete reached its peak [22]. J. Pacheco found that the higher the strength grade of concrete prepared with recycled aggregate, the higher the strength loss rate [23]. In addition, to save the amount of cement, some scholars use RP, a by-product produced in the process of recycled aggregate treatment, to partially replace cementitious materials in RP concrete preparation. Through their research on the performance of RP concrete, these scholars found that the performance of RP is similar to that of fly ash, which can provide certain hydration activity [23][24][25][26][27][28][29]; this provides a theoretical basis for the application of RP in concrete.

It is necessary to alleviate the pressure of construction solid waste on the environment and improve the resource utilization level of construction solid waste. In this paper, different kinds of RCA, RFA, and RP are combined to prepare full component recycled dry-mixed mortar and full component recycled concrete, and their performance is compared with pure natural aggregate mortar and concrete. SCRCA and SCRFA are obtained by simple-crushing the solid waste from construction; SCRCA and SCRFA are then processed by particle-shaping to obtain PSRCA, PSRFA, and by-product RP. After testing and analyzing the physical properties of products in different treatment stages, under the condition of a 1:4 cement-sand ratio and 100% use of SCRFA, PSRFA, and RS as fine aggregate, the dry mixed masonry mortar was prepared, using RP instead of cement with four replacement rates of 0%, 10%, 20%, and 30%, respectively. The basic and mechanical properties and microstructure of hydration products of dry-mixed mortar were analyzed, and the maximum substitution rate of RP was determined. Under the condition that the amount of cementing material is 400 kg/m$^3$ and the RP substitution rate is the largest, three different aggregate combinations to prepare concrete, the 100% use of SCRCA and SCRFA, PSRCA and PSRFA, RS and NCA, are used to analyze working and mechanical performance, and the transition zone of the aggregate interface of the prepared concrete.

## 3. Conclusions

Construction solid waste is prepared into different types of recycled coarse/fine aggregates through different treatment methods. The dry-mixed masonry mortar and concrete were prepared using 100% recycled coarse/fine aggregate and part by-product RP and compared with the dry-mixed masonry mortar and concrete prepared by using natural coarse/fine aggregate. By studying its basic and mechanical properties and microstructure, the following conclusions are drawn.

(1) After particle shaping, the performance of PSRCA and PSRFA is close to the basic performance of NCA and RS and is much higher than that of SCRCA and SCRFA.

(2) As the replacement rate of RP increases, the performance indicators of dry-mixed masonry mortar gradually decrease. To ensure the application of products in actual projects, the maximum replacement rate of RP should not be greater than 20%.

(3) When the RP replacement rate is 20%, the performance of the product can not only meet the requirements of use, but also reduce the amount of cement to the greatest extent, and realize the comprehensive utilization of waste resources, energy savings, and emission reduction.

(4) In the concrete prepared with different aggregate combinations, the failure mode of SCRCA and DCRFA concrete mainly damage the interface between the old and the new mortar, and the aggregate cannot play the role of skeleton support. The damage morphology of the concrete prepared by the PSRCA and PSRFA treated by the particle-shaping technology is the same as that of the NCA and RS concrete, and the damage is mainly caused by the crushing of the aggregate.

(5) In follow-up research, we can further study the influence of different types of aggregates on the performance of concrete, such as NCA and PSRFA, NCA and SCRFA, PSRCA and RS, PSRCA and SCRFA, etc.

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