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# Research on crushing and recycling of waste concrete

Wenbo Ai<sup>1</sup>, Hongmei Liu<sup>1,2\*</sup>, Jian Zhang<sup>1</sup>, Shuaishuai Lv<sup>1</sup>, Qian Xu<sup>2</sup> and Huanhuan Li<sup>3</sup>

<sup>1</sup>School of Mechanical Engineering, Nantong University, Nantong, Jiangsu, 226019, China

<sup>2</sup>School of Transportation and Civil Engineering, Nantong University, Nantong, Jiangsu, 226019, China

<sup>3</sup>School of Mechanical Engineering, NanTong Institute of Technology, Nantong, Jiangsu, 226002, China

\*Corresponding author's e-mail: liu.hm@ntu.edu.cn

**Abstract.** The development of recycling waste concrete in China and abroad is reviewed in detail together with a brief review of the recycling technology of waste concrete. Advantages, disadvantages and properties of recycled coarse aggregate, fine aggregate and fine powder are discussed through extensive analysis of the literature, and new trends in recycled material development are also presented.

## 1.Introduction

The construction waste generated during the demolition and construction of the building has placed a huge burden on the city. From 2013 to 2018, the annual production of construction waste in China increased from 1.297 billion tons to 1.704 billion tons. With the acceleration of urbanization, the number is increasing year by year. It is expected that the production of construction waste will reach its peak in 2020. Improper disposal of construction waste will not only encroach on a large amount of cultivated land, but also cause serious environmental pollution problem [1-2]. Construction waste usually consists of different types of concrete, mortar, tiles and other materials. Among them, waste concrete accounts for a large proportion.

## 2.Development of recycling of waste concrete

The use of waste concrete originated from the end of World War II. A large number of houses and roads were destroyed because of the war in Germany, Russia, Japan and other countries. It is considered feasible to recycle waste concrete to dispose of the building debris and obtain sufficient raw materials to rebuild the city [3]. After a large amount of construction waste had been destroyed, the recycling of construction waste began to decrease gradually. Until the 1970s, the idea of using recycled aggregates from waste concrete for unstructured structures was put forward again by American scholars [4]. Since then, research on recycling of waste concrete has been widely carried out in the United States, Japan, the European Union and other countries. At the same time, relevant laws have been issued to ensure the rational use of waste concrete in these developed countries and regions. The Netherlands enacted two regulations in 1995 and 1997 respectively, which prohibit the landfill of recyclable waste such as waste concrete, which must be used for recycling [5]. In Asia, Japan enacted the "Construction Materials Recycling Act" in 2000, requiring contractors to classify

and recycle waste generated during construction and demolition work. Japan's concrete recycling rate is the highest, about 98% of waste concrete have been recycled [6].

The research on recycled wall materials of waste concrete in China started late. Originally, the recycled aggregates obtained from waste concrete did not meet the relevant standards and the recycled aggregates were only used for foundation reinforcement, low-grade roads and urban walkway cushions. Since then, China has carried out extensive research on waste concrete crushing equipment and crushing technology. At present, a relatively mature waste concrete crushing process has been formed and put into production [7].

### **3. Crushing technology of waste concrete**

#### *3.1 Crushing technology of waste concrete abroad*

First, the crushing process adopted abroad is basically to remove the impurities such as metal, glass and wood from the waste concrete. After that, two times of crushing and sieving are carried out to further remove impurities in the sieving process, and finally recycled aggregate of various particle size levels is obtained.

The research on waste concrete started earlier in Russia. Since 1980, 40 million tons of waste concrete have been recycled in Russia. There are two rotor crushers in the crushing process of waste concrete, which can crush concrete blocks into three kinds of aggregates with different particle sizes [8,9]. In addition, the magnetic separation device is also set in the production process, which can effectively remove the iron impurities in the aggregate. However, the process requires a variety of mechanical equipment, so the initial investment cost is very expensive.

Germany has improved the corresponding production equipment and formed a set of high-level recycled concrete manufacturing process. The crushing process is similar to that in Russia [10,11]. Two jaw crushers and four sieves are used to decompose the concrete into four grades of aggregates with different particle sizes [12].

Compared with other production processes, the biggest difference of Japan's crushing production process is that it adds a heat treatment process between the first and the second crushing [13,14]. When the waste concrete is broken for the first time, the heating device is used to heat the concrete block to 300°C, at the moment, the cement mortar on the concrete surface becomes brittle and the binding performance with the aggregate is reduced, and then the cement mortar on the aggregate surface is effectively removed by the detritus equipment. The aggregate obtained by this treatment is better than that obtained by mechanical crushing alone. However, the disadvantage of this method is that the energy consumption will be increased because of the heating process.

#### *3.2 Crushing technology of waste concrete in China*

A set of production process suitable for China's actual situation was proposed by Xiao Jianzhuang, etc[15]. Firstly, the reinforcement and wood in the waste concrete block are removed manually, then the iron debris impurities are removed by using the magnetic separator and other devices, and then they are washed after the final screening, so as to remove clay, silt, fine debris and other substances as much as possible.

A method for the separation of all components of waste concrete was proposed by Zhang Linglei. In the beginning, the waste concrete is firstly broken by jaw crusher. After the primary crushing and screening, the recycled aggregate with the particle size greater than 9.5mm is divided into two particle size segments of 9.5-25mm and greater than 25mm, which are respectively put back into the crusher for secondary crushing. After crushing, it is screened and recycled aggregate with particle size larger than 4.75mm is mixed together. At the same time, all the recycled aggregate with particle size less than 4.75mm generated by crushing and the recycled aggregate with particle size less than 9.5mm generated during the first crushing are fully mixed. After crushing again, the recycled fine aggregate and the recycled fine powder with particle size less than 0.16mm are obtained by wind classification. The separation method of all components of waste concrete comprehensively considers the graded

crushing of recycled coarse aggregate, the comprehensive utilization of recycled fine aggregate and recycled micro powder, which lays a foundation for the effective utilization of all components of waste concrete.

#### **4. Broken products of waste concrete**

##### *4.1 Recycled coarse aggregate*

The grain obtained by crushing, cleaning and grading the waste concrete block are called recycled aggregate. There are many edges and corners on the recycled coarse aggregate and micro cracks inside.

The grain larger than 4.75mm used to prepare concrete are called recycled coarse aggregate. There are many edges and corners on the regenerated coarse aggregate, and there are micro cracks inside. Cement mortar is attached to the surface of recycled coarse aggregate. Compared with natural coarse aggregate, recycled coarse aggregate is of higher water absorption, lower apparent density and larger crushing index value [16].

The utilization of recycled coarse aggregate can effectively alleviate the shortage of natural aggregate supply. However, the quality of recycled aggregate is affected by the source of waste concrete. Most of the existing utilization methods use aggregate as pavement concrete aggregate, or as raw materials of low-strength pavement bricks and blocks. In the existing utilization methods, most recycled coarse aggregate have been used to prepare pavement concrete aggregate, or used as the raw material of low-strength pavement brick and pavement block. In this way, the maximum value of recycled coarse aggregate can not be exerted.

In order to improve the utilization rate of recycled aggregate, it is necessary to improve the properties of the recycled aggregate. The existing modification methods of recycled coarse aggregate include chemical strengthening, nano strengthening, biological strengthening, particle shaping and so on [17].

##### *4.2 Recycled fine aggregate*

After crushing, the grain whose particle size is smaller than 4.75mm are called recycled fine aggregate. Recycled fine aggregate is a kind of artificial aggregate with complex composition, low hydration activity and high permeability[18].

Recycled fine aggregate is mostly the by-product of mechanical modification of recycled coarse aggregate. For example, during the particle shaping of recycled coarse aggregate, the output of recycled fine aggregate is even higher than that of high-quality recycled coarse aggregate.

Recycled fine aggregate is mainly the broken product of mortar in waste concrete. Generally, recycled fine aggregate is mainly used in the preparation of recycled mortar. In order to improve the performance of recycled fine aggregate, a method of crushing recycled waste concrete into recycled fine aggregate is proposed [19]. The recycled fine aggregate contains about 40% of the crushed products of stone in waste concrete. After crushing, the detritus is similar to the machine-made sand in the way. The porosity and water absorption of recycled fine aggregate is reduced.

##### *4.3 Recycled fine powder*

Recycled fine powder is a kind of fine powder obtained by crushing and sieving waste concrete for many steps. Its particle size is less than 0.16mm. In the process of preparing recycled aggregate, mechanical impact caused by crushing, screening, strengthening and other processes will also produce such fine powder [20].

The inner part of regenerated powder is loose and its surface is rough. It is mainly composed of cement mortar and aggregate debris. The chemical composition of recycled micropowder is almost the same as that of cement, mainly contents CaO and SiO<sub>2</sub>[21]. The regenerated powder has potential activity because it contains C<sub>2</sub>S, C<sub>3</sub>S, SiO<sub>2</sub> and other active substances.

Recycled fine powder is mainly used as gel material or mineral admixture. Using recycled fine powder to replace cement can play a role of micro-aggregate. The mechanical properties and durability of concrete can be improved by replacing some common mineral admixtures such as fly ash or mineral powder with recycled fine powder [22].

### 5. Conclusions and suggestions

There is a foundation of the utilization technology of waste concrete in China. The properties of the recycled products have been studied and put into production and use. However, its utilization efficiency is low. In view of the problem of old mortar adhering to recycled aggregate, the recycling process of waste concrete needs to be optimized and improve the performance of its products, so as to improve its recycling efficiency. For regions with conditions, on the premise of ensuring quality, the construction company can be forced to use recycled products to replace natural materials in proportion. At the same time, the laws and regulations on construction waste recycling need to be established and improved by the government. Construction waste classification technology and management level need to be improved to enhance the quality of raw material recycling products and ensure the development of related industries.

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