Application of Industrial Solid Waste in Preparation of Recycled Concrete: A Review

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Abstract. In recent years, the increasing construction waste and industrial waste has brought great pressure to the environment, and finding a reasonable disposal method has become an important problem to be solved. Using recycled concrete as a new building material can not only protect the environment and achieve sustainable development, but also save construction costs. The large-scale use of recycled concrete will bring significant economic, social and environmental benefits, which is in line with the concept of green and sustainable development. This paper focuses on the feasibility research results on the application of recycled concrete as building materials and industrial solid waste in recycled concrete, and prospects the future development trend.

Keywords: Recycled concrete, construction solid waste, industrial solid waste, research status, development prospects.

1. Introduction
In recent years, a large number of old buildings have been demolished, resulting in a large number of construction waste. By 2020, China's construction waste production will reach 2.6 billion tons, which will not only affect the beauty, waste a lot of sites, but also cause environmental pollution. At present, the domestic construction waste treatment method is still in the simple landfill and stacking stage, and the alkaline waste generated in the process of landfill treatment will make a lot of soil unusable. By using waste concrete to make recycled aggregate, not only the dumping problem of construction waste is reduced, but also the exploitation of natural aggregate is reduced. Recycled concrete technology has the advantages of low energy consumption, renewable and so on, which is conducive to sustainable development, in line with the green development concept proposed in the 13th five-year plan. In addition to construction waste, industrial waste is also an area worthy of attention. Phosphonyls is an industrial by-product of wet process phosphoric acid production in phosphorus chemical enterprises. Phosphogypsum will be produced when sulfuric acid is used to react with phosphate rock to produce phosphoric acid. In 2017, China's phosphonyls emissions reached 75 million tons, and the accumulated storage reached 400 million tons. The comprehensive utilization of phosphonyls is far less than the production and emission of phosphonyls. Untreated phosphonyls not only occupies a lot of land, but also causes serious environmental pollution.
China attaches great importance to the utilization of solid waste resources, and the report of the 19th National Congress of the Communist Party of China emphasizes "promoting the comprehensive conservation and recycling of resources". This paper summarizes the research status of the application of construction waste and industrial solid waste in concrete, summarizes the existing problems, and in view of the existing problems, prospects the future research direction and application of recycled concrete.

2. Research status of construction waste resource utilization

The production of recycled concrete from construction solid waste has become a hot topic at home and abroad. At present, the research of recycled aggregate concrete has been carried out. Liu Qiong et al. [1] used digital image correlation technology to analyze the internal structure of waste concrete and waste brick recycled concrete. The mechanical property test showed that the waste brick aggregate had the smallest elastic modulus, but its compressive strength was higher than that of waste concrete aggregate. Cao Fubo et al. [2] conducted mechanical properties experiment on recycled coarse aggregate, and the results show that the recycled concrete mixed with fly ash and water-reducing admixture can significantly improve the working performance of concrete. Under a certain amount of fly ash, the 28d cube compressive strength of recycled concrete increases by 9.1% compared with ordinary concrete. Wu Jianpeng et al. [3] analyzed the performance of recycled coarse aggregate concrete with different modification schemes. The analysis results show that the compressive strength of recycled coarse aggregate concrete with 10% grade I fly ash is 22.8% higher than that without treatment, and the interfacial bonding strength is 40.9% higher than that without treatment, and the durability of recycled coarse aggregate concrete is the best at this time. Duan Dongxu et al. [4] established two-dimensional and three-dimensional random models of recycled concrete, carried out numerical simulation under uniaxial tension and compression, and concluded that the compression damage of recycled concrete specimens was caused by the concentration of internal tensile stress and shear stress, and the damage was caused by the concentration of internal tensile stress under uniaxial tensile load. Sun Xiaoyu et al. [5] analyzed the performance of recycled concrete with different recycled aggregate content. The test results show that when the water cement ratio is 0.43, adding recycled aggregate is the most favorable to control the collapse loss. When the replacement rate of recycled aggregate is 40% - 70%, the flexural strength of recycled concrete can be improved, and the carbonation resistance is the best when the content of recycled aggregate is 100%. Li Wei et al. [6] analyzed the mechanical properties of recycled concrete with different replacement rates of recycled aggregate. The results show that the strength requirements can be met when the replacement rate of recycled aggregate is less than 30%. When the replacement rate is 100%, the compressive strength and splitting tensile strength decrease by 38% and 30%, and the flexural strength decreases by 27%. Li Dahe et al. [7] carried out sulfate corrosion resistance test on recycled concrete with different replacement rate of recycled aggregate. The test results show that when the replacement rate of recycled aggregate is more than 50%, the sulfate corrosion resistance of recycled concrete is reduced, and the higher the content of chloride salt, the better the inhibition effect on sodium sulfate corrosion resistance of recycled concrete. Wen Huaiqing et al. [8] tested the mechanical properties of recycled concrete, and the results showed that when the replacement rate of recycled aggregate was 25%, 30% and 35%, the cube compressive strength of recycled concrete decreased by 27.95%, 29.39% and 34.20% compared with ordinary concrete. Xiao Bei et al. [9] analysed the influence of the replacement rate of recycled aggregate on the mechanical properties of recycled concrete. Due to the accumulation of micro cracks in the use of recycled coarse aggregate, the strength of recycled concrete is reduced. The compressive strength is the best when the replacement rate is about 80%, the splitting tensile strength is the best when the replacement rate is about 40%, and the flexural strength is the best when the replacement rate is about 25%. Xu Mengbo et al. [10] analyzed the replacement rate of recycled coarse aggregate from different sources under the conditions of 30%, 50%, 70% and 100% respectively, and found that the cube compressive strength and axial compressive strength of recycled concrete are higher than those of ordinary concrete. Hongru Zhang et al. [11] treated the surface of recycled aggregate with strengthening slurry prepared by sulphoaluminate. The research
shows that the surface of recycled aggregate treated by sulfoaluminate strengthening slurry and sulfoaluminate processing waste basalt powder has obvious improvement in workability, compressive strength, compactness and corrosion resistance of chloride ion and sulfate. Shen Yan et al.

3. Application of industrial solid waste in recycled concrete

The increasing of industrial waste has brought great pressure to the environment. At present, the existing treatment methods cannot meet the needs of social development. Improving the application of industrial solid waste has become a hot issue at home and abroad. Using industrial solid waste to produce "green cement" is an effective way to solve the problem of massive accumulation of industrial solid waste. Fan Jie et al. [12] analyzed the mechanical properties of high-volume fly ash cement. When 60% fly ash is added, the flexural strength of mortar is basically the same as that of ordinary mortar, but the compressive strength decreases. Dai Yilei et al. Wang Xuelian et al. [13] explored the mechanical properties and shrinkage characteristics of fly ash micro bead reactive powder concrete. The test results show that the compressive strength and working performance of fly ash micro bead reactive powder concrete are the best when the content of fly ash micro bead is about 30% and the water binder ratio is about 0.16. Wang Xiaoli et al. [14] analyzed the current disposal methods of industrial solid waste in China, and concluded that at present, industrial solid waste is mainly used in new wall materials, porous sound-absorbing materials, glass ceramics and other new building materials, but further research and discussion are needed to avoid secondary pollution. Zheng Xu et al. [15] measured the water resistance coefficient of different amount of phosphonys, and the results showed that when the amount of phosphonys was 40%~50%, the cement slurry had good water resistance. Yang Jie et al. [16] studied and analyzed the optimization method of anti-carbonization performance of SSPG slag cement, and the results showed that improving the fineness of phosphonys slurry powder and using superplasticizer can effectively improve the anti-carbonization performance of SSPG slag cement. Li Lei et al. [17] studied the compressive performance, tensile performance and flexural performance of recycled concrete with different amount of hybrid fiber. The results show that when the proportion of steel fiber increases and the proportion of PVA fiber decreases, the compressive strength increases in the range of 0.6%-19.1%, the tensile strength increases in the range of 1.8%-70.9%, and the flexural strength increases in the range of 18.9%~19.1%. Ding Xiangqun et al. [18] studied the influence of mineral powder, silica fume and fly ash on sulfoaluminate cement Ordinary portland cement composite system. The conclusion shows that the addition of mineral powder and fly ash can reduce the drying shrinkage, while silica fume can increase the drying shrinkage. The addition of mineral admixtures can improve the sulfate resistance of the specimens. Huang Jiaojiao et al. [19] compared and analyzed the performance of sulfoaluminate cement concrete and ordinary portland cement concrete, and the results showed that the strength of sulfoaluminate cement concrete was higher than ordinary portland cement concrete; when the water cement ratio was the same, the impermeability of sulfoaluminate cement concrete was higher than ordinary portland cement concrete, but when 20% admixture was added, the conclusion was opposite. Long an et al. [20] obtained the highest strength when the water cement ratio was 0.36 by analyzing the influencing factors of the strength of different water cement ratios of phosphorus gypsum slag cement, and the strength decreased when the water cement ratio was reduced. Yan Shen et al. [21] studied the mechanical properties of sulfoaluminate cement prepared from industrial solid waste phosphonys. The results show that the sintering temperature of sulfoaluminate is basically the same as that of phosphonys decomposition, and phosphonys can reduce the content of calcium sulfoaluminate in cement at higher temperature.

4. Collaborative utilization of construction waste and industrial solid waste

Taking construction waste and industrial solid waste as the main raw materials, through the composite of recycled aggregate and green cement, the full solid waste recycled concrete suitable for stressed components of building structure is developed, which realizes the collaborative disposal and efficient utilization of construction solid waste and industrial solid waste, and further realizes the resource utilization of solid waste. Wang Guolin et al. [22] studied the mechanical properties of recycled concrete
with different replacement rates of recycled coarse aggregate and fly ash. The results show that when the slump is satisfied, the compressive strength, prism compressive strength and elastic modulus of recycled concrete decrease with the increase of replacement rate of recycled aggregate, and increase with the increase of replacement rate of fly ash. Cui Peng et al. [23] studied the influence of fly ash and silica fume on the mechanical properties and durability of recycled concrete. The results show that fly ash and silica fume have adverse effects on the mechanical properties of recycled concrete, but the combined effect of the two can significantly improve the durability of recycled concrete. By testing the compressive strength of recycled concrete with different replacement rates of fly ash and coarse aggregate, Zhang Shihua et al. [24] found that when the replacement rate and age of fly ash are the same, the most suitable replacement rate of recycled coarse aggregate is controlled below 30%, and when the replacement rate and age of recycled coarse aggregate are the same, the replacement rate of fly ash is controlled around 10%, which is the most suitable replacement rate.

5. Conclusion
This paper analyzes the research status of recycled concrete, on this basis, analyzes and summarizes the existing problems in the field of recycled concrete. The development of recycled concrete technology is more and more mature, but there are still many difficulties to be overcome in large-scale application. At present, the main problems of recycled concrete are poor mechanical properties and high cost. Solving these problems is the main research direction of large-scale application of recycled concrete. The study of mechanical failure mechanism of solid waste recycled concrete combined with building solid waste and industrial solid waste is a new research direction of recycled concrete. The development trend of recycled concrete can be summarized as follows:

(1) At present, the research on the collaborative utilization of construction solid waste and industrial solid waste to produce recycled concrete is not mature enough, and the related research has not been carried out on a large scale. It is necessary to deeply study the influence of the replacement rate of recycled aggregate and the incorporation of industrial solid waste phosphogypsum and fly ash on the mechanical properties of concrete, and whether the recycled concrete can meet the basic mechanical properties of building structure.

(2) There are few studies on the preparation of green cement with sulphoaluminate as the main component, which is energy-saving, material saving and low emission by phosphonyms. The basic composition design and hydration hardening mechanism of phosphonyms fly ash cement are the theoretical basis for the preparation of phosphonyms fly ash cement from industrial solid waste.

(3) The technology of using centimeter grade recycled coarse aggregate (waste concrete crushing) and micron grade phosphonyms fly ash cement to prepare recycled concrete is the key technology of recycled concrete full solid waste design.

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