Interfacial transition zone characteristics of recycled concrete: A review

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Abstract. China and other developing countries are the largest consumers of concrete. The massive use of concrete consumes natural resources and produces construction waste, which leads to the shortage of landfill sites. Using recycled aggregate to prepare concrete cannot only meet the performance requirements of natural aggregate concrete, but also solve the problem of insufficient landfill site, which is in line with the essence of sustainable development. However, the interfacial transition zone is often the weak area of recycled concrete, which is the focus of current research. This paper summarizes the mechanical properties of recycled concrete ITZ, studies the existing problems, and looks forward to the future development trend.

Keywords: recycled concrete, interfacial transition zone, mechanical properties, sulfoaluminate cement.

1. Introduction

In the 21st century, with the rapid development of urbanization and industrialization, construction industry consumes a lot of natural resources and produces a lot of construction and demolition waste. The construction industry has become one of the industries with the greatest impact on the environment [1]. Concrete is widely used in construction industry because of its low price and stable performance. Concrete is a composite material made of a certain proportion of cementitious materials, water, aggregate and additives. The construction industry in the world produces about 25 billion tons of concrete every year [2]. At present, China and other developing countries are the largest consumers of concrete [3]. The extensive use of concrete has caused a series of problems, such as the consumption of natural resources, the generation of construction waste, resulting in the shortage of landfill sites. In recent years, more and more experts and scholars begin to pay attention to the sustainable development of concrete. Recycled concrete, as an environment-friendly material, has attracted more and more attention. Aggregate in concrete usually accounts for 60% - 75% of the volume of concrete, and natural aggregate will not be produced in a short time [4]. Waste concrete is produced from the demolition of buildings. The waste concrete is recycled, crushed and mixed according to a certain proportion, and then recycled concrete is prepared as recycled aggregate instead of natural aggregate [5-6]. Using recycled aggregate to prepare concrete cannot only meet the performance requirements of natural aggregate concrete, but also solve the problem of insufficient landfill site, which is in line with the essence of
sustainable development. The application of recycled concrete in practical engineering has good economic and environmental benefits [7-8].

As early as 1946, Gluzhge carried out relevant research and demonstrated the practical possibility of using waste concrete as recycled aggregate. By the end of the 1970s, the amount of waste concrete used in the former Soviet Union had reached 40 million tons [9]. Xiao Jianzhuang et al. [10,11] have done a lot of research on the physical and mechanical properties of recycled concrete. Through the uniaxial compression test of recycled concrete, it is found that there is little difference in fatigue properties between recycled concrete and ordinary concrete. Through pull-out test, the load slip curve between recycled concrete and steel bar under different replacement ratio is obtained, which is similar to that of ordinary concrete. Chen Zongping et al. [12] conducted triaxial compression test on 68 recycled concrete cylinder specimens, and obtained the load slip curve under different replacement ratio of aggregate, lateral confining pressure value, age, source of recycled aggregate and concrete strength grade. Cao Wanlin et al. [13] summarized the existing research work on recycled concrete, pointed out the key technologies that need to be further studied, affirmed that recycled concrete can be used for structures that need seismic design. Bai Guoliang et al. [14] carried out the low cycle repeated load test of recycled concrete frame columns with different aggregate replacement rates. The results show that the failure process of recycled concrete frame columns is basically similar except that the ductility and energy dissipation capacity of recycled concrete frame columns are worse than that of ordinary concrete frames.

Recycled coarse aggregate is mainly produced by waste concrete. Compared with natural coarse aggregate, the porosity of recycled coarse aggregate is larger, which is mainly because the old cement mortar adheres to the matrix aggregate particles [15-16]. In addition, the introduction of recycled coarse aggregate increases the type of ITZ of recycled concrete. Recycled concrete consists of ITZ1, ITZ2 and ITZ3, which are between the coarse aggregate and the new mortar, and between the coarse aggregate and the old mortar. Under the same conditions, recycled concrete has more and more complex interface weak areas than ordinary concrete, which is the essential difference between ordinary concrete and recycled concrete in fine and micro structure, and is the fundamental reason for the deterioration of recycled concrete materials, components and structural performance, so there are problems in recycled concrete transition area [17].

2. Study on interface transition zone of recycled concrete

Sun Zengzhi [18] pointed out that as long as the measures are scientific and reasonable, the mechanical properties of recycled concrete can meet the actual needs of the project, and the improvement of the properties of recycled aggregate is mainly to strengthen or remove the adhesion mortar of recycled aggregate; the replacement rate of recycled aggregate and water cement ratio are one of the key considerations in the mix design of recycled concrete. Xiao Bei et al. [19] found that the proportion of original old mortar in the cement mortar bonding interface of fresh concrete will reduce the actual water cement ratio, reduce the bonding interface bearing capacity, and cause the strength of recycled concrete to decrease. Li Wengui et al. [20] found that increasing the strength of the old mortar wrapped around the recycled aggregate is an important measure to improve the mechanical properties of recycled concrete based on the water absorption, porosity and compactness of the original old mortar around the recycled aggregate. Xiao Jianzhang et al. [21] pointed out that there are many pores and Ca (OH)2 in the interface transition area of new and old mortar, and discussed the indentation modulus of recycled aggregate concrete interface transition area by using nano indentation technology. The results show that the new interface transition area is the main factor leading to the strength reduction of recycled aggregate concrete. Based on this, Guo Peng et al. [22] proposed that the mechanical properties of recycled aggregate concrete are seriously affected by the aggregation and directional arrangement of Ca (OH)2 in the interface transition zone of recycled aggregate concrete. Shao Yunhong et al. [23] pointed out that compared with natural concrete, the interfacial transition zone of recycled concrete is the weak area of recycled concrete, so it is necessary to strengthen the theoretical research on the interfacial transition zone, and actively explore the removal method of recycled aggregate wrapped cement mortar from waste concrete.
Zhu Xiaoyun [24] obtained the reasonable material composition of recycled concrete and explained the improvement mechanism of fly ash on sulfate corrosion resistance of recycled concrete by testing the influence of material ratio, concrete compressive corrosion resistance coefficient and mass loss rate, and observing the micro morphology of three kinds of interface transition zone in recycled concrete by SEM. Fang Yihan [25] conducted durability and mechanical properties tests on recycled concrete wrapped with slurry, and obtained that recycled concrete wrapped with slurry has better durability than recycled concrete without slurry, higher compressive strength, especially late strength, and improved interface transition zone performance. Yue Gongbing [26] tested and analysed the microhardness of multiple interface transition zone of recycled concrete with different strength grades, studied the multiple interface structure of recycled concrete and its influence on performance damage, and concluded that improving the strength grade of recycled concrete can effectively increase the microhardness of mortar matrix and interface transition zone. Qin Heying [27] measured the anti-chloride ion permeability of the test block by using the rapid chloride ion permeability test, and concluded that the interface area of concrete is the weak link of its anti-chloride ion permeability, and the addition of silica fume can better improve the performance of the interface area. Gao Song [28] observed the enrichment of Ca element and Si element in the interface area by means of SEM and EDS, and observed the location and scope of the interface transition area of recycled concrete after ion erosion, which was consistent with the microhardness results.

Wang Zhongxing [29] et al. determined the width of different interface transition zone of different strength grade recycled concrete by studying the change of microhardness of different interfaces of recycled concrete corroded by sulfate, studied the influence of sulfate corrosion period on the microstructure of different interfaces of recycled concrete, and concluded that with the increase of strength grade of recycled concrete, the microhardness of the same interface increased. Wan Huiwen [30] et al. treated recycled concrete by reducing water binder ratio, adding 20% fly ash and 2.5% superplasticizer (for cement), obtained that reducing water binder ratio, adding appropriate amount of water reducer and adding a small amount of fly ash can improve the structure of ITZ of recycled concrete, narrow the gap between aggregate and cement paste, and reduce the porosity, Increase the probability of new cement paste hydration products bonding with the old concrete surface, improve the compressive strength of concrete.

Sulphoaluminate cement is a cementitious material with anhydrous calcium sulfoaluminate, dicalcium silicate and calcium ferric aluminate as main mineral components. Due to the low energy consumption and less carbon dioxide emission in the production process, sulphoaluminate cement is expected to be promoted as a substitute for ordinary portland cement. However, the production of sulphoaluminate cement requires a large amount of high-grade bauxite, which hinders the wide application of sulphoaluminate cement.

The interfacial transition zone (ITZ) of recycled concrete prepared with ordinary portland cement usually contains calcium hydroxide, hydrated calcium silicate, etc. Compared with hydrated calcium silicate, the specific surface area of calcium hydroxide is very small, the intermolecular force is weak, and the crystal arrangement has a certain orientation in the hydration process, so its contribution to the mechanical properties is limited. Therefore, reducing the content of calcium hydroxide crystal in ITZ is a possible way to improve the properties of ITZ. In view of this, considering that sulphoaluminate cement does not generate calcium hydroxide crystals in the hydration process, it is expected that sulphoaluminate cement can be used to modify recycled concrete. In addition, compared with ordinary portland cement, sulphoaluminate cement has obvious advantages of early strength, shrinkage resistance, sulfate resistance and chloride resistance. In recent years, the research and development of sulphoaluminate cement production from phosphonys and other industrial solid wastes are rapid. Using sulphoaluminate cement to prepare recycled concrete is expected to reduce the content of calcium hydroxide crystal in ITZ structure, improve the compactness of ITZ structure, and then improve the mechanical properties of recycled concrete.
3. Conclusion
This paper summarizes the research status of recycled concrete at home and abroad, and on this basis, studies the mechanical properties and interface transition zone of recycled concrete. Most scholars mention the interface transition zone of recycled concrete, but the research is insufficient. The sulphoaluminate cement mentioned in this paper can improve the performance of interface transition zone of recycled concrete;

(1) The interface transition zone of recycled concrete is relatively weak. In recent years, the research and development of sulphoaluminate cement production from phosphogypsum and other industrial solid wastes are rapid. The development of this field, to a certain extent, solves the cost problem that hinders the large-scale application of sulphoaluminate cement, so that sulphoaluminate cement is expected to replace ordinary portland cement in recycled concrete.

(2) The large-scale application of sulphoaluminate cement in practical engineering provides a good theoretical support. In order to further improve the comprehensive utilization of bulk solid waste and realize the collaborative and efficient disposal of industrial solid waste and construction solid waste.

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