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Research Status of Mechanical Properties of Recycled Concrete Under Freeze-thaw Cycle

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Abstract

In recent years, with the increasing awareness of environmental protection, the reform and development of the construction industry have been promoted. There is always a large amount of waste concrete in the process of building production. The reuse of this part of concrete has become a hot issue for people. There are many problems in the process of reusing this part of concrete, especially the recycled concrete itself has great problems. Based on a large number of literatures, this paper reviews and analyzes the influence of the basic properties of recycled concrete, such as the influence of the change of pore distribution of recycled concrete and the influence of the mechanical properties of recycled concrete under the freeze-thaw cycle. It is hoped to provide reference for the research of mechanical properties of recycled concrete in the future.

Keywords

Environmental protection; Freeze-thaw cycle; Recycled concrete; Basic performance; Mechanical property.

1. INTRODUCTION

With the rapid development of China's economy and urbanization, the construction industry has witnessed rapid development. In addition, the output of discarded concrete has been increasing year by year. The average annual amount of construction garbage produced in China has exceeded 1.5 billion tons, and the total amount of construction garbage has exceeded 20 billion tons [1]. We usually use landfill for treatment, which not only occupies a large amount of land, but also causes huge pollution to the environment [2], which is not in line with the concept of green and sustainable development. Therefore, we need to effectively treat and reuse the discarded concrete .

Thus, the concept of Recycled Aggregate Concrete (RAC) was developed, which is the new concrete prepared by recycled aggregate obtained after waste concrete was processed through a series of technological processes (including smashing, particle screening, etc.) according to a certain construction mix ratio. In order to make better use of recycled concrete, it is necessary to study its basic mechanical properties, especially to fully understand its relevant characteristics when using recycled concrete as building materials in a specific environment, so as to make better use of this green resource [3]. And there are many ways to use this green material [4]. Based on the basic mechanical properties of concrete, the author discusses the related properties of recycled concrete under freeze-thaw cycle, so as to provide some references for better research and utilization of recycled concrete under freeze-thaw cycle.

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2. RESEARCH STATUS OF MECHANICAL PROPERTIES OF RECYCLED CONCRETE

Current studies have shown [5] that the use of recycled aggregate results in reduced compressive strength compared to the original aggregate. Concrete made with recycled coarse aggregate showed the largest reduction in strength of 5-24% compared to concrete made with raw aggregate. It should be noted that when both coarse aggregate and fine aggregate are obtained from recycled concrete, the strength reduction is between 15% and 40% compared to concrete made using only natural materials. The application of reclaimed aggregate in reclaimed concrete is limited due to its many edges, rough surface, micro-cracks, high porosity, water absorption and high crushing value. Scholars at home and abroad have put forward a variety of modification and strengthening methods of recycled aggregate, mainly including physical reinforcement, chemical reinforcement and so on.

3. RESEARCH STATUS OF MECHANICAL PROPERTIES OF RECYCLED CONCRETE UNDER FREEZE-THAW CYCLE

There are many reasons for the failure of concrete structures. A large number of examples tell us that in many cases, the failure of concrete structures is not caused by insufficient strength, but by insufficient durability, which leads to the failure of freeze-thaw cycle. Many scholars at home and abroad have conducted researches. For example, He Yuanyuan et al. studied the reinforcement of recycled concrete short columns under freeze-thaw cycle, and concluded that CFRP reinforcement measures can repair the damage caused by freeze-thaw cycle to the bearing capacity and durability of recycled concrete, and increase the ultimate bearing capacity by 51.4%. Zhu et al. [6] 's research results show that the mechanical properties of recycled concrete prepared with 100% reused fine aggregate or coarse aggregate always decrease gradually with the increase of the number of cycles.

Figure 1. Example of chlorine salt erosion under freeze-thaw cycle in north China

According to Chinese literature review, the main reason for the damage of concrete structure in northern China is freeze-thaw and salt-freeze. When the concrete structure is subjected to freeze-thaw cycle, fine and microscopic cracks appear inside, thus accelerating chloride ion transmission, and the coupling of double deterioration factors will further accelerate the decline of structural durability. As shown in Figure 1, the freeze-thaw cycle leads to surface spalling and macro cracks of concrete, etc. At the same time, chlorine salt erosion also causes corrosion of internal steel bars. This chapter starts with freeze-thaw cycle, and gradually introduces the influence of freeze-thaw cycle on the mechanical properties of recycled concrete.

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3.1. Effect of replacement rate on freeze-thaw cycle of recycled concrete

Qiao Hongxia et al. [7] designed a comparative test under different substitution rates and carried out freeze-thaw cycle test of recycled concrete by using the quick-freezing method. The results show that when the substitution rate is 20%, the freeze-thaw cycle resistance of recycled concrete is the strongest. With the increase of replacement rate, the anti-freezing cycle capacity of recycled concrete decreases greatly. Liu et al. [8] also found that with the increase of RCA replacement rate, the frost resistance of RAC decreases, which reduces the mechanical properties of the material layer, and thus leads to the reduction of the bearing capacity and ductility of the structural layer. Liu et al. [9] conducted a drawing test and found that as the number of freeze-thaw cycles increased, the higher the replacement rate of recycled concrete was, the more obvious the bond strength decreased.

In addition, Wei Yimeng et al. [10] conducted freeze-thaw tests by changing the replacement rate of recycled concrete based on nuclear magnetic resonance technology. The research shows that the relationship between the replacement rate of recycled aggregate and the frost resistance of recycled concrete is not regular. When preparing recycled concrete, the replacement rate of recycled aggregate is about 50%. FIG. 2 shows the NMR T2 distribution curves at different substitution rates.

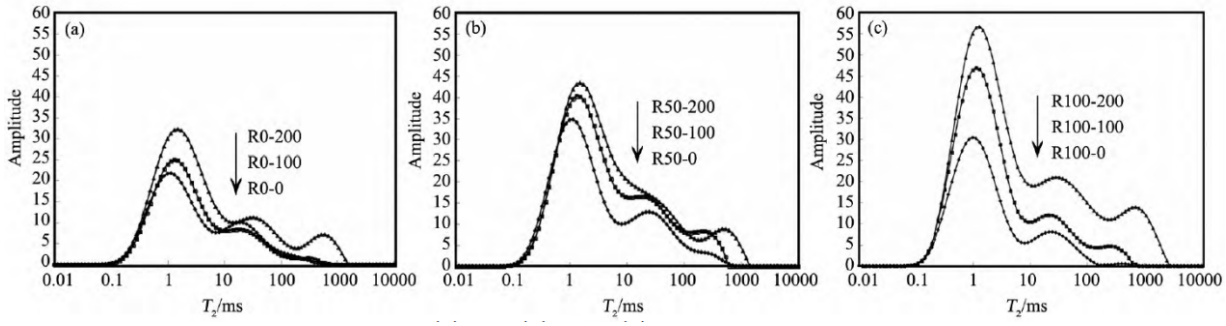

Figure 2. NMR T2 distribution curves of R0(a), R50(b) and R100(c)

Chen Zhoung et al. [11] found that when the water-binder ratio was 0.52, the higher replacement rate of recycled fine aggregate would lead to the deterioration of the frost resistance of concrete. Moreover, cement slurry can also be used to fill the cracks of recycled aggregate and improve its interface structure, so as to improve the impermeability and frost resistance of recycled concrete.

Therefore, under the action of freeze-thaw cycle, the replacement rate of recycled concrete should not be too high, which will reduce the frost resistance of concrete, and it is suggested that the proportion of recycled aggregate should not exceed 30%.

3.2. Influence of admixture on freeze-thaw cycle of recycled concrete

In terms of frost resistance, when fly ash (PFA) admixture reaches 30%, the frost resistance of recycled concrete is the strongest. When the pulverized blast furnace slag (GGBS) reaches 60%, the frost resistance of recycled concrete is similar to that of ordinary Portland cement (OPC). As shown in Figure 6.

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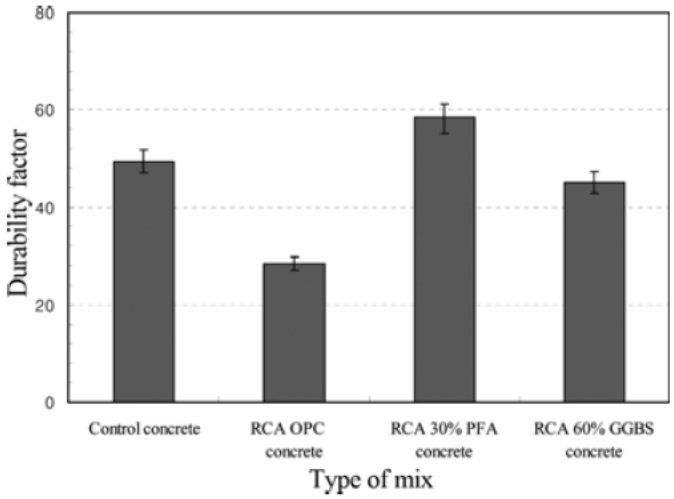

Figure 3. RCA durability coefficient of concrete

Liu et al. [24] used three types of non-entrained concrete and one type of entrained concrete to prepare concrete, and studied three mixing methods. The results show that with the increase of the strength of reclaimed coarse aggregate raw concrete, the water absorption and crushing index of reclaimed concrete decrease, while the dry density of saturated surface and the content of residual mortar increase. In addition, the recycled coarse aggregate has a lower dry density on the saturated surface and a higher crushing index, which is due to the inclusion of air in the parent concrete.

It is worth noting that although the cement slurry wrapped aggregate method and the two-stage mixing method improve the mechanical properties of air-entrained reclaimed aggregate concrete, they have no significant effect on its freeze-thaw resistance. On the other hand, air-regenerated aggregate concrete samples prepared with recycled coarse aggregate obtained from non-air-entrained concrete show poor frost resistance.

Li et al. [25] studied the influence of the combined action of freeze-thaw cycle and sulfate erosion on the freeze-resistance of low-content fly ash (LVFA) and high-content fly ash (HVFA) concrete prepared with recycled coarse aggregate. The results showed that the concrete mixture's resistance to F-T cycle and sulfate attack increased with the increase of CRCA content during the replacement of CNA.

It is worth noting that 5% sodium sulfate solution has similar improvement on the freeze-thaw cycle performance of low fly ash and high fly ash concrete, while 5% magnesium sulfate solution has obvious reduction on the freeze-thaw cycle performance of HVFA concrete.

4. PROSPECTS

At present, people pay more and more attention to green sustainable development. Our country is advocating saving resources, protecting the environment, and trying to practice the green concept of green water and green mountains is gold mountain and silver mountain. In architectural engineering, recycled concrete is the concrete embodiment of this idea. The research on this aspect has been a hot topic at home and abroad.

Some foreign developed countries such as the United States, Japan and so on have a relatively perfect treatment of waste concrete. For example, the United States has a sound construction waste treatment system. In 1980, the US government stipulated in the Superfund Act that "any enterprise producing industrial waste must properly dispose of it by itself and shall not dump it arbitrarily". In 1996, the United States improved the legal system on the utilization of solid waste, such as resource recycling, renewable demonstration, scientific and technological

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development, and recycling standards. Japan has a land area of about 370,000 square kilometers, which is short of various resources. Due to the limitation of its own geographical location, it has been committed to the recycling of resources. Since the 1960s, Japan has enacted a series of laws on the disposal of construction waste. Currently, the recycling rate of construction waste is as high as 95%. In 2002, Singapore implemented the "Green Plan 2012 Waste Reduction Action Plan", which takes waste reduction as an important development goal and increases the cost of construction waste discharge to reduce construction waste discharge.

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