Strengthening method of waste concrete aggregate

Abstract

After the construction solid waste is broken, it is directly used as recycled aggregate, which often has the disadvantages of large porosity, high water absorption and low strength, resulting in low strength and poor durability of the recycled concrete prepared by it. Therefore, the effective use of recycled aggregate in concrete is limited. For this reason, researchers have carried out systematic research on the modification of recycled aggregate in order to realize the reuse of resources. The research shows that the strengthening methods of recycled aggregate can be divided into physical methods, chemical methods and microbial methods to make up for the defects of recycled aggregate. In this paper, the concrete content of recycled aggregate strengthening method is reviewed, which provides some theoretical support for the treatment of construction waste and its utilization as recycled aggregate.

Key words: recycled aggregate; Physical strengthening; Chemical strengthening; Microbial enhancement

Introduction

As one of the essential materials in civil engineering, concrete is widely used in urban construction, transportation infrastructure construction and other fields. If only natural stone is used to produce concrete, excessive mining of sand and stone is bound to cause serious damage to the ecological environment. At the same time, a large number of old houses are demolished, and construction waste cannot be effectively dealt with, thus causing serious problems [1][2]. The development of recycled concrete aggregate recycling can not only provide treatment for construction waste, but also alleviate the pressure of natural aggregate shortage. However, compared with natural aggregates, recycled aggregates have the characteristics of low apparent density, high porosity, rough surface, high water absorption, high crushing value, and more micro-

cracks, all of which are caused by the presence of adhesive old mortar [1][3][4]. In addition, recycled concrete also has some disadvantages such as large water consumption, large shrinkage, poor mechanical properties and limited durability [5][6][7][8]. These disadvantages greatly limit the application of recycled concrete in practical engineering.

How to strengthen the construction waste as a recycled aggregate to completely or partially replace the natural aggregate such as sand and stone to produce concrete, the key is to strengthen the treatment of recycled aggregate. At present, the strengthening method of recycled aggregate has become a hot topic in the research of recycled aggregate. Therefore, in this paper, the strengthening methods and existing problems of recycled aggregate are reviewed and summarized.

1. Recycled aggregate treatment method

1.1 Physical Strengthening

Physical strengthening, as the most commonly used method, relies on mechanical equipment to polish the broken recycled aggregate, so that the collision and friction between the aggregate and the aggregate or between the aggregate and the mechanical equipment can remove the mortar attached to the surface of the recycled aggregate and excessive corners, so that the appearance of the recycled aggregate is closer to the natural aggregate.

The heating grinding method developed by Japan Sanling Company [9] first heats the recycled coarse aggregate that is simply broken and the particle size is less than 40 mm to more than 300℃, so that the cement mortar attached to the surface of the recycled aggregate is dehydrated and embrittle, and then the recycled coarse aggregate treated at high temperature is put into the grinding equipment to effectively remove the old mortar on the surface of the aggregate. There are also the vertical eccentric device grinding method [10][11][12] proposed by Takenaka Works Shop in Japan and the horizontal mechanical forced grinding method [13][14] developed by Pacific Cement Co., LTD., both of which enable the recycled coarse aggregate to grind off the mortar under the action of high-speed rotating eccentric wheel and wear-resistant lining plate, thus strengthening the recycled coarse aggregate.

Kathy Bru et al. [15] used microwave heating to treat the reclaimed aggregate and finally obtained the sample with low fracture energy. Drawing on foreign experience, Professor Li Qiuyi from Qingdao University of Technology proposed particle shaping technology, which uses a high-speed rotating spreader plate to drive the high-speed movement of aggregate and produce centrifugal effect. Through the collision and friction between aggregate and machinery or between aggregate and aggregate, the mortar layer on the surface of aggregate is automatically peeled off, eliminating excess edges and corners, and getting better grain shape. Reclaimed coarse aggregate with low water absorption and crushing index is an effective physical strengthening method at present in China. Ma[16] used heating method to treat building waste concrete and obtained recycled aggregate with good quality. Russian research shows that the modified treatment of recycled coarse aggregate by ball mill can reduce crushing index and water absorption, and improve the quality of recycled coarse aggregate [17].

However, it is undeniable that physical strengthening methods usually consume energy and cost more, and are easy to cause the formation of micro-cracks inside the recycled aggregate, causing physical damage.

1.2 Chemical Strengthening

The chemical method uses chemical solution to spray, soak and dry the recycled coarse aggregate, so that a substance in the chemical solution reacts with a substance in the recycled aggregate, removes the attached mortar, or fills and repair the voids and micro-cracks of the recycled coarse aggregate, reduces the porosity of the aggregate and improves the strength of the aggregate.

① Polymer emulsion treatment

Polymer emulsion treatment is to soak or spray recycled aggregate by taking advantage of the polymer emulsion's good adhesion and hydrophobicity, and can be cured and formed in a short time. Polymer molecules can quickly fill the micro-cracks inside the recycled aggregate and the micro-pores attached to the hardened cement mortar, and at the same time form a dense impervious film on the surface of the recycled aggregate. Thus, the water absorption of recycled aggregate is reduced.

When regenerated aggregate is impregnated with PVA, Kou et al. [23] fill the pores

attached to hardened cement mortar with PVA molecules, densify its structure and reduce its porosity, which can greatly reduce the water absorption rate of regenerated aggregate. Wang Fuxing [19] showed that the water absorption of reclaimed fine aggregate modified by PVA decreased by 58.3%, while the effect of VAE emulsion was not obvious. Both Tsuiino[20] and Spaeth[21] modified reclaimed aggregates with silane polymer could reduce the water absorption of reclaimed aggregates, but the reduction effect was related to the type of polymer. Xiao Kaitao [22] treated recycled aggregate with polymer solution and organic waterproofing agent, resulting in a decrease in 24h water absorption of 57% and 74%, respectively. Shi-Cong Kou et al. [23] impregnated recycled aggregates with polyvinyl alcohol, which improved the mechanical properties and chloride ion penetration resistance of recycled concrete.

② acid treatment

The regenerated aggregate is soaked in acid solution (such as CH3COOH, H3PO4, HC1, H2CO4), and the acid solution is used to chemically react with the hardened cement mortar (CaO, Al2O3, Fe2O3, etc.) attached to the surface of the regenerated aggregate to peel the hardened cement mortar and improve the surface morphology of the particles.

Tam et al. [24] used HCl, H2SO4 and H3PO4 to soak the recycled aggregate, all of which could reduce the content of adhesive hardened cement mortar on the surface of the recycled aggregate, thus reducing the water absorption. Purushothaman et al. [25] treated the reclaimed coarse aggregate with HCl, H2SO4, scrubs and heating washing, and found that the reclaimed coarse aggregate obtained by H2SO4 treatment and heating washing treatment had a low water absorption rate, and other properties were similar to those of natural coarse aggregate. The strength of recycled aggregate concrete is very close to that of natural aggregate concrete. Soren et al. [26] studied 5 kinds of strengthening methods for recycled coarse aggregate, and found that soaking with 5% dilute HCl solution improved the water absorption of recycled coarse aggregate significantly, and the crushing value decreased less. Wang Jianghao et al. [27] used H2CO4 solution and HC1 solution to treat recycled coarse aggregate by chemical leaching, which could effectively remove the adhesion of hardened cement mortar on

the surface of recycled coarse aggregate and reduce water absorption. Ha-Seog Kim et al. [28] used sulfuric acid and hydrochloric acid to remove the adhesive mortar on the surface of recycled aggregate to reduce the water absorption of recycled aggregate.

③ Treatment of volcanic ash slurry

Pozzolanic slurry treatment method is a modified and strengthened treatment method based on pozzolanic slurry reaction. When active powder slurry such as fly ash silica fume and diatomite is used to treat recycled aggregate, the hardened cement mortar attached to the surface of recycled aggregate can stimulate the pozzolanic effect of the active powder and the micro-aggregate filling effect, and fill the micro-cracks inside the recycled aggregate and the micro-pores in the surface hardened cement mortar. Reduce porosity.

Katz[29] applied ultrasonic cleaning and wollastonite slurry soaking to treat recycled aggregate, and found that the soaking treatment with wollastonite slurry had a significant improvement effect. Tam [30][31] et al. used pure cement slurry and cement plus silica slurry to treat recycled aggregate, and found that both can improve the structure of attached slurry and the transition zone of the old interface. After adding silica ash, the structure of recycled aggregate and the transition zone of the new and old interface become denser, and the effect is better. Zhang Xuebing et al. [32][33] used active powder cement slurry and slurry containing homogeneous distribution of ultra-fine particle dense system to soak and encapsulate recycled coarse aggregate, both of which could reduce the crushing index of recycled coarse aggregate, enhance the density of interfacial transition zone, improve the strength, and RPC slurry had better strengthening effect. Sun Yuedong et al. [34] modified recycled aggregate with 4 different chemical grout. Fan Xiaoping et al. [35] found in the experimental study that adding 12%UEA expansion agent, 5% inorganic aluminum salt composite waterproofing agent and 10% silica ash to pure cement slurry and cement slurry respectively had different soaking effects on recycled aggregate, and concluded that inorganic composite solution had the best soaking effect. Du Ting et al. [36] also found through the test that adding Kim powder, silica powder and grade fly ash to pure cement slurry and cement slurry respectively had different soaking and strengthening effects

on recycled aggregate. According to the conclusion, adding Kim powder slurry to cement has obvious improvement effect on recycled coarse aggregate and is better than the other three kinds of slurry.

④ Water glass solution treatment

Water glass solution treatment method refers to the reaction of water glass solution with calcium hydroxide to generate C-S-H and silicic acid gel, fill the micro-cracks inside the recycled aggregate and the micro-pores attached to the hardened cement mortar on the surface of the recycled aggregate, solidifying the hardened cement mortar attached to the surface of the recycled aggregate [37], so as to refine the pore size, reduce the porosity and reduce the water absorption rate. In addition, the water glass solution treatment method can also wash the dust, mud and impurities attached to the surface of the recycled aggregate, and has the modification effect of wet treatment.

Guo Qijie et al. [38] used water glass solution, silicone resin and silane coupling agent to soak recycled aggregate, and the performance of recycled aggregate after treatment was improved to varying degrees, among which the treatment effect was best when the concentration of water glass solution was 30% and the temperature was 180℃. Yang Feihua et al. [39] showed that when 3% water glass solution was soaked for 1h at room temperature, the 7d, 28d and 60d compressive strength of recycled concrete prepared with recycled aggregate was increased by 30.6%, 27.1% and 17.8% respectively, indicating a large increase. Cheng Haili et al. [40][41] studied the effect of sodium silicate solution concentration and soaking time on the modification and strengthening of recycled aggregate. It is found that the strength of recycled concrete prepared with recycled aggregate can be significantly improved by soaking water glass solution with 5% concentration for 1h. However, when the recycled aggregate is soaked in high concentration and for a long time, it will affect the strength of recycled concrete, and the influence mechanism is not clear.

⑤ Carbonization treatment

Carbonization reaction modification treatment of regenerated aggregate is based on carbonization reaction, using the surface of regenerated aggregate to attach $Ca(OH)_2$ and C-S-H in hardened cement mortar with CO2, and the resulting CaCO3 crystal and

silicic acid gel to fill the internal micro-cracks of aggregate and attach the hardened cement mortar micro-pores, so that the overall structure of regenerated aggregate becomes dense. Thus, porosity is reduced, water absorption of recycled aggregate is reduced, and strength is improved [42].

Kou et al. [43] studied the effect of carbonization treatment on regenerated aggregate with 100% CO2 concentration and reaction time as a variable in the test. The research shows that the application of CO2 can improve the physical properties of recycled aggregate, and with the extension of curing time, the more full the degree of carbonization, the greater the improvement of the performance of recycled aggregate, the higher the quality of aggregate. Pan Ganghua et al. [43] invented a method to strengthen recycled concrete fine aggregate by carbonizing carbon dioxide. Compared with untreated recycled fine aggregate, the water absorption rate was reduced by nearly 53% and the crushing value was reduced by nearly 45%. Li Yake [45] adopted CO2 to strengthen the treatment of reclaimed fine aggregate, which can effectively improve the apparent density, reduce the water absorption rate and crushing index, and make the performance of reclaimed fine aggregate after treatment more similar to that of natural fine aggregate.

1.3 Microbial enhancement

Microbial method is to promote the precipitation of calcium carbonate in different environments by the biological control and induction process of microorganisms to make up for the defects of recycled aggregates.

Singh et al. [46] studied the strengthening effect of ureahydrotic bacteria and non-ureahydrotic bacteria on recycled aggregate, and the results showed that both of the above two bacteria could improve the performance of recycled aggregate, among which Bacillus ureahydrotic showed better mineralization potential, which once again verified the characteristics of ureahydrotic microorganisms with fast reaction and high efficiency. Salman Rais et al. [47] used microbial mineralization technology to explore the impact on the performance of recycled aggregate concrete, and found that calcium carbonate precipitation generated by MICP technology can fill the internal pores and holes of concrete to make its structure more dense, and thus significantly improve its

strength, durability and other properties. In summary, microbial mineralization deposition technology is a feasible method that is expected to achieve ecological friendliness, but this method is greatly affected by conditions and is still in the experimental test stage, requiring further research.

2 Conclusions

The current strengthening methods have relatively obvious effects on the recycling of recycled aggregate. Although there are advantages and disadvantages in the strengthening process, it is undeniable that these strengthening technologies provide strong technical support for the utilization of recycled aggregate. Relatively speaking, it has good results and application prospects for the strengthening of adhesive mortar on aggregate surface. Relatively speaking, it has good results and application prospects for the strengthening of adhesive mortar on aggregate surface. In this kind of strengthening method, after the treatment of aggregate by volcanic ash slurry, the aggregate performance improvement effect is relatively good, the operation is simple, the cost is saved, and the secondary pollution will not be caused in the process.

3 summary

The current research mainly focuses on the improvement of a single strengthening method, and there are few studies on two or more methods of compound strengthening recycled aggregates. Therefore, how to use appropriate strengthening methods to strengthen aggregates, so that the performance of aggregates can reach or even exceed that of natural aggregates, so as to solve the shortage of natural aggregates and the phenomenon of wanton landfill of construction waste. It is still one of the problems that concrete workers need to pay attention to.

In addition, the design mix ratio of recycled aggregate concrete must be prepared before construction, and the reasonable design of the mix ratio of concrete can ensure that the structure can withstand the design load and maintain stability and safety during its service life. Secondly, the cost of pretreatment of recycled aggregate and the cost of natural aggregate should be balanced to achieve the win-win effect of saving cost and improving the utilization rate of recycled aggregate.

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