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Review on Strengthening and Application of Reclaimed Concrete

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Abstract

With the continuous increase in urbanization, the annual output of construction waste has consistently grown at a high speed. Based on extensive research and comparative analysis of relevant literature, this paper summarizes recent reinforcement methods for recycled concrete aggregate. The primary obstacle to utilizing construction waste resources is the significant amount of old cement mortar attached to the surface of recycled aggregate. This not only increases water absorption rate but also creates numerous weak interface transition zones in recycled concrete, greatly impacting its performance. By comparing and analyzing a large number of relevant literature on removing old cement mortar and enhancing the strength of recycled concrete interfaces, this paper examines their advantages, disadvantages, applicability, environmental benefits, etc., and proposes corresponding suggestions for developing recycled concrete aggregate technology. These findings aim to provide new insights into future research directions for reinforcing recycled concrete aggregates.

Keywords

Recycled Concrete; Strengthening Method; Aggregate; Mechanical Properties.

1. Introduction

Environmental protection should pay attention to the saving of resources, the more efficient saving and use of resources, the reform of the use of resources, the fundamental change of the way of resource utilization, optimize the management problems in the production process caused by the waste of energy, the high cost, the low efficiency of resource use and production efficiency. Strengthen the high circulation, small consumption, high utilization and repeated circulation of resources in the production process. At the present stage, there are mainly the following methods for the treatment of construction waste: landfill, dumping, construction waste re-use of brick, dry mortar making and so on. In different building materials, the energy consumption and carbon emissions of cement and concrete account for a very large proportion, which has a great impact on the environment and sustainability. Reclaimed concrete refers to the concrete prepared by using waste concrete in part or in whole to replace natural concrete aggregate (mainly coarse aggregate) under complex conditions after crushing, cleaning, screening and grading. Because it can not only solve the environmental problems caused by the demolition of waste construction (construction), but also replace some natural stone, solve the increasing shortage of natural aggregate; is a major measure for the utilization of construction waste resources, which has been highly valued by the academic and engineering circles. However, compared with natural aggregate, recycled concrete aggregate has low density, high water absorption rate and large porosity, which lead to the reduction of mechanical performance indexes of recycled aggregate. Moreover, recycled aggregate is attached to old mortar, with the interface transition zone of "old coarse aggregate-old mortar".

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2. Defects of Recycled Aggregate

Reclaimed aggregate is a material with similar properties to natural aggregate after removing the reinforcement of old concrete and being crushed by a crusher.Recycled aggregate is not a uniform single body with more edges and corners than natural aggregate and the presence of residual old cement mortar on the surface.The main problem of using recycled aggregate as a building material is that the bond strength between the residual old cement mortar and the new cement mortar is low, and the old cement mortar has a high porosity and water absorption rate.The preparation of recycled concrete with recycled aggregate is easy to form more weak interfaces in the interior of concrete, and the more residual mortar, the more weak interfaces, which will not only increase the risk of chloride ions entering the interior of concrete [3], but also have a negative impact on the mechanical properties and durability of concrete [4], and then affect the performance of recycled concrete.

3. Physical Reinforcement Method

3.1. Mechanical Strengthening

Mechanical treatment is the most commonly used, simplest and most effective method for treating recycled aggregate. Mechanical treatment is mainly through mechanical external force to crush and remove the residual old cement mortar.The recycled aggregate is processed by jaw crusher, granulator and ball mill, among which the recovery rate of recycled aggregate is as high as 80%.After the first grinding of the recycled coarse aggregate, the second grinding and crushing is carried out, it is found that the reinforced recycled aggregate basically restores the original characteristics of natural gravel coarse aggregate, but it will produce more micropowder causing secondary pollution.DIMITRIOU et al. [5] remove smaller particles and adhering mortar and screen.The aggregate particles after strengthening are round in shape, and the method is more simple than other mechanical strengthening methods.

Mechanical strengthening method is the simplest and most widely used method. Although it can effectively remove the residual cement mortar on the surface of recycled aggregate, the performance of recycled aggregate may be damaged in the process of collision and friction, and may introduce microcracks [6], which has obvious disadvantages such as large energy consumption, mechanical wear and secondary pollution.The effect and income of reinforcing recycled aggregate by mechanical grinding alone are not ideal. In the future, it is a good path to combine mechanical strengthening method with other strengthening methods.

3.2. Heat Treatment Method

Heat treatment has been considered as a good treatment method for removing bonded mortar, mainly due to its simple operation and high cost-effectiveness. The principle of heat treatment is that the hydration products of cement, calcium silicate hydrate and calcium hydroxide, are decomposed at 60-250 °C and 450-500 °C respectively [7], thereby weakening the bonding strength of cement mortar and aggregate, and then removing the old cement mortar by physical methods.Studies have found that when the recycled aggregate is heated at a temperature higher than 300 °C, the bonding effect of aggregate and mortar becomes weak, and it is easy to peel the mortar away from the aggregate [8]; Yoon [9] et al. showed that the recycled aggregate was first calcined at 600 °C for 1 h drying, and then ground for 1 ~ 12 h, which can effectively remove the mortar attached to the surface of the recycled aggregate, and the calcination can remove the magazine and clay minerals, and the recycled aggregate is more pure after treatment.The higher the heating temperature, the easier the mortar is removed. When the heating temperature exceeds 750°C, the residual water-mud-sand mortar can be almost completely removed. But it is pointed out that when the heating temperature is higher than 500 °C, the performance of the recycled aggregate may degrade [10]. The treatment efficiency of

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microwave heating treatment for recycled aggregate with a particle size greater than 20 mm is up to 65.1% [11].

It can be seen that heating treatment has a high reliability for removing the old cement mortar residue on the surface of recycled aggregate, but both traditional heating treatment and microwave heating treatment need to consume a lot of energy to heat up, and its environmental benefits are not high. When physical grinding, cracks will occur in the aggregate, affecting the strength of the aggregate. It is not practical from an economic point of view. In recent years, some scholars have also studied the related problems of high temperature damage and energy consumption of aggregate, and found that the mortar was removed by vibration after low temperature heating, which reduces energy consumption while considering the strengthening effect. In the future, the appropriate heating temperature and grinding strength need to be explored. When the recycled aggregate is largely discrete, the suitable conditions for the strengthening method may be different. Considering the energy consumption, aggregate quality and other factors, it is suggested to adopt low temperature treatment (about 450 °C) to improve the quality of recycled aggregate by improving the grinding strength and time.

3.3. Wet Treatment Method

Wet treatment strengthening method is to use water to pretreat the recycled concrete aggregate, separate and remove the dirt, organic matter, broken brick impurities and so on in the recycled concrete aggregate, so as to obtain better quality aggregate.Wang Lingling et al. [12] conducted a simple pre-wetting treatment on the recycled concrete aggregate before mixing the recycled concrete, and found that this method had a positive effect on the water resistance, water absorption rate and 28 d compressive strength of the recycled concrete, and had little effect on the apparent density of the recycled concrete.The wet treatment strengthening method has certain limitations on the reinforcement of recycled concrete aggregate.The study on the use of ultrasonic washing technology to clean recycled aggregate found that for the recycled concrete aggregate with weak matrix, the loose particles on the surface of the recycled concrete aggregate can be removed, and the bonding force between the recycled concrete aggregate and the new cement slurry can be enhanced [13].When the replacement rate of recycled aggregate is 30% or 50%, the compressive strength increases with the increase of the pre-wetting amount of the recycled concrete at the same replacement rate. When the replacement rate of recycled concrete is 70% or 100%, the compressive strength increases with the increase of the pre-wetting amount of the recycled concrete at the same replacement rate [14]. The recycled aggregate is immersed in the ultrasonic bath for 10 min, and then cleaned for 10 min with clear water. Repeat several times until the water cleaned the aggregate becomes clear, and the cleaning cycle of the concrete with high strength is less than that of the concrete with low strength. Through the ultrasonic cleaning technology, the loose particles on the surface of the recycled aggregate can be removed, and the bond strength between the new cement slurry and the recycled aggregate can be improved. The recycled coarse aggregate prepared by the ultrasonic cleaning technology can improve the compressive strength of the recycled concrete by 7% [15].

This method is relatively simple, and it is not easy to cause a large number of micropowders produced in the process of mechanical grinding. At the same time, it has a certain effect on enhancing the interface bonding force.The wet treatment has a certain effect on the water absorption rate of the recycled aggregate.But the strengthening effect of only using water washing is very limited. For the low grade cement base, more fine particles will be produced, and many cycles of cleaning will make the process consume a large amount of water resources, increase the difficulty of the process, and it is difficult to put into large-scale engineering use.

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4. Chemical Strengthening

4.1. Carbonization

Carbonation is the process of CO2 gas in the surrounding environment diffusing to the interior of concrete through the pores of concrete and dissolving in the pore water, which reacts with alkaline substances in concrete.The alkalinity, water absorption rate and crushing value of recycled concrete aggregate decrease after strengthening, the apparent density increases, and the compressive strength of recycled concrete improves.Gao Yueqing et al. [16] found that the alkalinity of recycled concrete aggregate after CO2 strengthening was significantly reduced, about 2.61~3.82.Luo et al. [17] found that the water absorption rate and crushing value of recycled concrete aggregate were reduced after carbonation, which were 27.1% and 4.8% lower than those without strengthening, and the apparent density increased by 0.5% compared with that without strengthening.Under the same substitution rate, the compressive strength and elastic modulus of carbonized recycled concrete aggregate concrete were higher than those of uncarbonized recycled concrete aggregate concrete, which were 13.1%, 5% and 5.8%, respectively.Zhang et al. [18] also found that the compressive strength of reinforced recycled concrete was 13.0% ~32.9% higher than that of unstrengthened recycled concrete.CO2 can react with cement hydration products to form calcium carbonate and silica gel, and the carbonation reaction products can cover the pore wall in the mortar, reducing the porosity of recycled aggregate.

The physical performance of recycled concrete aggregate strengthened by CO2 is very significant for the improvement of concrete compressive strength. Carbonation can not only enhance the performance of recycled aggregate and recycled concrete, but also enhance the durability of recycled concrete. CO2 reinforced recycled concrete aggregate is a sustainable development technology with practical benefits, which can not only improve the performance of recycled concrete, but also realize the storage and utilization of CO2, and can achieve the benefit of 1+1>2. The carbonation process does not introduce new ions and new components, but it should be noted that the pH value and the ability to bind chloride ions of the carbonated aggregate will be reduced, and the carbonation degree should be controlled to avoid excessive residual calcium hydroxide, increasing the risk of alkali aggregate reaction. CO2 reinforced recycled concrete aggregate is still in the experimental stage. The subsequent research can start from engineering practice to determine the best carbonation conditions under the engineering background, find a method for large-scale carbonation of recycled concrete aggregate, and carry out the evaluation research on the economy and environmental performance of the practical application of CO2 reinforced recycled concrete aggregate.

4.2. Soaking in Chemical Solution

Soaking in chemical solution is mainly aimed at the defects of large porosity and high water absorption rate of the old mortar residue on the surface of recycled aggregate.The essence is to introduce chemical ions, which react with the cement mortar and form sediments and flocs to fill the pores of recycled aggregate, so as to reduce the water absorption rate and porosity. The main reason for the low strength of recycled concrete is that the poor bonding between the old cement mortar and the new cement mortar residue on the recycled aggregate is easy to form a weak interface.Sodium silicate solution and water glass (main components are SiO2 and Na2O) can react with the old cement mortar and produce C-S-H gel with bonding effect, thus strengthening the bonding between the old and new cement mortar and enhancing the strength of concrete interface. Relevant studies have shown that the recycled aggregate after modification can improve the mechanical properties of recycled concrete by more than 10% [19]. Song Xuefeng et al. conducted tests on the carbonation resistance and freezing resistance of recycled concrete at different ages under different moduli, and obtained carbonation

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resistance similar to that of natural concrete when the modulus was 2.8. The treatment effect of a single reagent is relatively simple, so a combination of multiple reagents can be used to treat recycled aggregate to achieve better improvement effect. For example, using a mass fraction of 5% sodium silicate solution and 10% silane solution combined treatment of coarse particles of recycled aggregate, the improved coarse particles of recycled material water absorption rate decreased by 57.1%, while improving the strength of 35.8% of recycled concrete [20].

The compressive strength of recycled concrete aggregate after reinforced by inorganic solution is significantly improved, and the durability can be comparable to that of natural concrete, with certain benefits.But the research depth of the durability of reinforced recycled concrete is far from enough.It is worth noting that the chemical solution soaking will increase the harmful substances in the recycled aggregate, such as acid root ions will bring harm to the alkaline concrete;excessive alkaline environment increases the risk of alkali aggregate reaction. Some chemical reagents have poor compatibility with recycled concrete, and the price is high, and excessive use will cause pollution to the environment.

4.3. Organic Solution Strengthening

PVA solution, as a water-soluble polymer often used as a building adhesive material, also has good effects for strengthening recycled concrete aggregate. It can not only fill the pores and microcracks on the surface of recycled concrete aggregate, but also form a hydrophobic layer wrapped on the surface, thereby reducing water absorption. The mass fraction of PVA and the strengthening treatment method have significant effects on the compressive strength of modified recycled concrete. Kou et al. [21] found that when the recycled concrete aggregate was soaked in PVA solution with different mass fractions, the best strengthening effect was achieved with a mass fraction of 10%, and after strengthening treatment, the water absorption rate of recycled concrete aggregate was significantly reduced and the compressive strength was improved [22]. In addition, the strengthening treatment method also has an important impact on the performance of recycled concrete. Yang et al. [23] sprayed PVA solution and added cement slurry to increase the bonding force between cement and recycled concrete aggregate, and made polyvinyl alcohol better fill into the pores and microcracks, thus improving the compressive strength of recycled concrete by about 22% compared with that of unstrengthened recycled concrete. In general, PVA mainly improves the compressive strength of recycled concrete by reducing water absorption rate, and the proper selection of reasonable mass fraction and the use of appropriate strengthening treatment method are essential for achieving good results.

According to the above comprehensive analysis, polyvinyl alcohol (PVA) solution has a significant strengthening effect on recycled concrete aggregate, which can greatly reduce its water absorption rate. It is worth noting that different mass fractions of PVA solution have different effects on the mechanical properties and durability of recycled concrete. In order to take into account the performance of concrete and realize the effective treatment of PVA waste liquid, the determination of the optimal mass fraction should be the focus of future research and engineering application. Specifically, it is necessary to further explore the mechanism of action of PVA solution with different mass fractions in recycled concrete, and how these solutions affect the compressive strength, bending strength, permeability and other key indicators of concrete. How to determine the optimal mass fraction to take into account the influence of concrete performance and the treatment of PVA waste liquid can be the focus of future research and engineering application.

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5. Conclusion

1) The composition of recycled concrete aggregate is complex, the source is diverse, the service life and the damage degree is different, and the single modification effect has limitations. Select the appropriate modification method according to the actual situation, and increase the research on the composite treatment of a variety of modification methods to meet the requirements. In order to strengthen the recycled concrete aggregate and improve its performance, it is necessary to understand its failure mechanism and take different improvement measures.

2) The weak area of recycled concrete aggregate is located in the interface transition zone. Although the area is small, it has a great impact on the strength of concrete. Therefore, strengthening the interface transition zone is an indispensable technical way to improve the performance of recycled concrete aggregate. In order to apply recycled concrete in engineering practice and ensure that it master the comprehensive performance index under various environmental effects and stress conditions, it is necessary to establish an effective detection mechanism. Through the study of the difference between the durability of recycled concrete and ordinary concrete, and comprehensive analysis, further breakthroughs are made in improving the durability of recycled concrete aggregate reinforcement method.

3) The physical reinforcement method includes mechanical reinforcement, heating treatment, wet treatment, etc. The mechanical reinforcement method can effectively remove the residual cement mortar on the surface of recycled aggregate, but the collision and friction process may damage the performance of recycled aggregate. It is suitable for large-scale and low-demand situations. Heat treatment, wet treatment energy consumption is high cost, suitable for small-scale treatment, the future can consider combined with mechanical treatment to improve economic efficiency.

4) chemical strengthening methods have carbonization treatment, inorganic solution soaking treatment, organic solution strengthening treatment, chemical strengthening method has not yet formed a perfect system, in the laboratory small-scale research stage which carbonization strengthening recycled concrete aggregate is a sustainable development technology with practical benefits.In the case of improving the compressive strength of recycled concrete by controlling the carbonization conditions, while improving the chloride ion resistance of concrete, it has a good prospect for development.

References

[1] B W Guan, J Y Wu, H X Chen, et al.Test of Coverage Rate of Residual Mortar on Recycled Aggregate and Its Influence on Permeability of Concrete[J]. China Journal of Highway and Transport,Vol. 34 (2021) No. 10, p.155-165.

[2] W M Shaban, J Yang, H Su, et al. Quality improvement techniques for recycled concrete aggregate: a review[J]. Journal of Advanced Concrete Technology, Vol. 17 (2019) No. 4, p.155-167.

[3] G Dimitriou, P Savva, M F Petrou. Enhancing mechanical and durability properties of recycled aggregate concrete[J]. Construction and Building Materials,Vol. 158 (2018) No. 15, p.228-235.

[4] K P Verian, W Ashraf, Y Cao. Properties of recycled concrete aggregate and their infuence in new concrete production[J]. Resources,Conservation and Recycling, Vol. 133 (2018) , p.155-167.

[5] B Lothenbach, F Winnefld, C Alder, et al. Effect of temperature on the pore solution, microstructure and hydration products of Portland cement pastes[J]. Cement and Concrete Research,Vol. 34 (2007) No. 4, p.483-491.

[6] H Shima, H Tateyashiki, R Matsuhashi, et al. An advanced concrete recycling technology and its applicability assessment through input-output analysis[J]. Journal of Advanced Concrete Technology, Vol. 3 (2005) No. 1, p.53-67.

ISSN: 2710-0588

[7] H S Yoon, E A Seo, D Gkim, et al. Efficiency of dry calcination and trituration treatments for removing cement pastes attached to recycled coarse aggregates[J]. Consttrucion and Building Materials,Vol. 312 (2021) , p.125-132.

[8] H K A Al-bayati, P K Das, TIGHE S L, et al. Evaluation of various treatment methods for enhancing the physical and morphological properties of coarse recycled concrete aggregate[J]. Construction and Building Materials,Vol. 112 (2016) , p.284-298.

[9] Lippiatt N,Bourgeois F. Investigation of microwave-assisted concrete recycling using single-particle testing [J]. Minerals Engineering,2012,31: 71-81.Vol. 31 (2012) p.71-81.

[10] L L Wang, Y W Chen, PAN Wen-hao, et al. Effects of wet processing technology on physical properties and mechanical behaviors of recycled concrete[J].Concrete,(2012) No. 12, p.24-26.

[11] A Katz. Properties of Concrete Made With Recycled Aggregate from Partially Hydrated Old Concrete[J]. Cement and Concrete Research, Vol. 33 (2003) No. 5, p.703-711.

[12] Y D Guo, Y Z Liu, W J Wang, et al. Effects of w ater consumption of prew etting recycled coarse aggregate on compressive strength of recycled thermal insulation concrete[J].Concrete,(2017) No. 5, p.82-85.

[13] A Katz. Treatments for the improvement of recycled aggregate[J]. Journal of Materials in Civil Engineering,Vol. 16 (2004) No. 6, p.597-630.

[14] Y Q Gao, P H Pan, LIANG C F,et al. Properties of CO2-modified recycled aggregates and its effect on the performance of recycled aggregate concrete[J].Journal of Civil and Environmental Engineering, Vol. 43 (2021) No. 6, p.95-102.

[15] LUO S,WU W,WU K.Effect of recycled coarse aggre-gates enhanced by CO2 on the mechanical properties of re-cycled aggregate concrete[J].IOP Conference Series:Mate-rials Science and Engineering, Vol. 431 (2018) No. 10, p.1-8.

[16] ZHANG,JK,SHI,et al.Influence of carbonated recycled concrete aggregate on properties of cement mortar[J].Con-struction &Building Materials,Vol. 98 (2015) , p.1-7.

[17] Q Q Chen. Study on mechanical properties of sodium silicate modified construction waste aggregate concrete[J].Concrete,106.(2022) No. 7, p.99-102.

[18] E C Wang, L H Yu, JIANG Xinpei,et al. Effect of Recycled Coarse Aggregate Pretreated with Chemical Solutions on Modification of Recycled Concrete[J].Bulletin of the Chinese Ceramic Society,Vol. 41 (2022) No. 12, p.4310-4317,4323.

[19] S C Kou,C S Poon.Properties of concrete prepared with PVA-impregnated recycled concrete aggregates[J]. Cement & Concrete Composites, Vol. 32 (2010) No.8, p.649-654.

[20] Y G Zhu, P Z Xu. Experimental research on modified of recycled aggregate concrete by silane and PVA[J].Concrete,(2015) No. 3, p.93-195.

[21] N Yang, C G Wang, ZHAO Meixia. Research on intensifying technique of recycled aggregate[J].New Building Materials,2011(3):45-47.(2011) No. 3, p.45-47.