ISSN: 2414-1895 DOI: 10.6919/ICJE.202112_7(12).0076

Research Progress of Recycled Coarse Material Strengthening

Jie Wang

Henan Polytechnic University, Jiaozuo 454150, China.

Abstract

Due to the existence of old mortar on the surface of recycled aggregate, the physical properties of recycled aggregates are inferior to those of natural coarse aggregate. This can results in large discreteness of mechanical and durability properties of recycled concrete, which is lower than that of ordinary concrete. In order to improve the mechanics and durability of recycled concrete, scholars have done a lot of research on the modification and strengthening of recycled aggregate. This paper mainly summarized the modification and strengthening methods of recycled aggregate. And the effects of different modification methods on the physical properties of recycled aggregate and the physical and mechanical properties of recycled concrete were discussed.

Keywords

Recycled aggregate, strengthen, physical property, mechanical property.

1. Introduction

With the rapid development of society and the advancement of urbanization, on the one hand, China's construction waste emissions increased year by year. On the other hand, the development of the construction industry consumes a lot of sand resources every year. From the perspective of environmental protection and sustainable development of construction industry, it is necessary to recycle waste concrete efficiently. Therefore, some scholars put forward the concept of recycled concrete. However, due to the existence of old mortar and micro-cracks on the surface of recycled aggregate, the performance of recycled concrete is inferior to that of natural concrete in all aspects. In order to realize the sustainable and healthy development of the construction industry, countries around the world have strengthened the research on recycled aggregate and recycled concrete technology.

The existence of old mortar on the surface of recycled aggregate, on the one hand, makes the water absorption of recycled aggregate much higher than that of natural aggregate, and the water consumption calculated by ordinary concrete mix ratio is no longer applicable to recycled concrete. Besides, the crushing index of recycled aggregate is higher than that of natural aggregate, which makes the physical and mechanical properties of recycled concrete lower than that of ordinary concrete. In addition, due to the different sources of recycled aggregate used by different researchers, the content and mechanical properties of old mortar are also different, which leads to the high discreteness of the current test structure. In order to make the physical properties of recycled aggregate close to natural aggregate, a large number of scholars have carried out research on the modification of recycled aggregate.

At present, the strengthening of recycled aggregate is mainly carried out by directly removing the old mortar or strengthening the old mortar. The commonly used methods are physical enhancement method, chemical enhancement method and microbial enhancement method.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202112_7(12).0076

2. Physical enhancement

External force or high temperature are mainly used as physical enhancement to remove the residual old mortar in recycled aggregate, so as to improve the quality of aggregate. While the external force or high temperature will cause new cracks and damage in the aggregate [1]. At present, the physical strengthening methods mainly include mechanical grinding, heating grinding, microwave heating and wet treatment.

2.1 Mechanical grinding

Mechanical grinding method uses mechanical equipment to drive recycled coarse aggregate collide with each other, so that the weak adhesion mortar on the surface of recycled coarse aggregate falls off. The reinforced recycled aggregate is clean and smooth [2]. Li et al. [3, 4] found through the study of aggregate particle shaping that the performance of recycled aggregate after particle shaping and strengthening was significantly improved. The performance of some high-quality recycled coarse aggregate was even comparable to that of natural gravel, and the performance of recycled fine aggregate was also significantly improved.

2.2 Heat grinding

The principle of heat treatment modified recycled aggregate, on the one hand, the difference of thermal expansion coefficient between mortar and natural aggregate makes the aggregate appear mortar stripping phenomenon in the heating process. On the other hand, the use of high temperature promotes the decomposition of compounds in the attached mortar, further stripping the old mortar from the natural aggregate by reducing the mortar cementation performance [5].

Su [6] analyzed the influence of heating temperature and constant temperature time on recycled aggregate. When the heating temperature is 500 °C, the performance of recycled aggregate improves significantly; when the temperature is 700 °C, although the removal rate of old mortar is high, the aggregate is destroyed by too high temperature, which leads to the increase of aggregate crushing value. Constant temperature heating time does not significantly improve the performance of aggregate.

2.3 Microwave heating

Microwave heating is to heat the aggregate by microwave, so that the surface mortar and the internal aggregate form a temperature difference. Removing Surface Mortar under Temperature Stress [5]. Through microwave heating modification tests, Zhao Haixin [7] found microwave power, single heating duration and cycle times were the main factors affecting the shedding rate of mortar. At the same time, the combination of microwave heating and mechanical grinding can obtain better modification effect. Wang Jian [8] carried out experiments in the medium power range. From the perspective of energy utilization and economy, it is better to use 960W microwave heating-water cooling cycle for 10 times.

3. Chemical enhancement method

In order to achieve the purpose of strengthening the recycled aggregate, the chemical method mainly puts the recycled aggregate into the chemical solution to make the solution react with the aggregate to remove the old mortar on the surface of the aggregate or directly fill the pores and cracks in the aggregate. The strengthening methods mainly include acid treatment, carbonization treatment and solution soaking.

3.1 Acid treatment

The working principle of acid corrosion method is to corrode the old mortar. When the recycled aggregate is immersed in the acid solution, the alkaline cement stone is easy to react in the acidic environment, and the loose and porous old mortar part is more obvious by acid corrosion effect [9]. Yu Kai [10] recycled coarse aggregate by hydrochloric acid impregnation, the best leaching time is 2h, the best impregnation concentration is 3%. After immersion in 3% hydrochloric acid for 2h, the water absorption of recycled coarse aggregate decreased by 20.3%, crushing index decreased by

ISSN: 2414-1895 DOI: 10.6919/ICJE.202112_7(12).0076

16.15%. Wang Jianghao et al. [11] .used different mass fractions of hydrochloric acid solution to impregnated recycled coarse aggregate in the experiment. The results show that the strengthening effect of 2% hydrochloric acid on recycled coarse aggregate and the improvement of compressive strength of recycled concrete are the most significant. Tam et al.[12] used HCl, H_2SO_4 and H_3PO_4 three acidic solutions to soak the recycled aggregate to remove the old mortar. The results showed that the water absorption of the pretreated aggregate was significantly reduced and the mechanical properties of the modified recycled concrete were improved. At the same time, the alkalinity, chloride and sulfide contents in the concrete were not affected by the treatment methods.

3.2 Carbonization treatment

Using CO_2 to strengthen recycled aggregate can make the calcium hydroxide (Ca (OH) $_2$) and calcium silicate hydrate (C-S-H) in the surface old mortar react with CO_2 to generate calcium carbonate ($CaCO_3$) and silica gel to fill the pores and cracks in the surface old mortar, so as to improve the quality of recycled aggregate and improve the performance of RAC[13-15]. Ying Jingwei[16] used high concentration CO_2 to strengthen recycled coarse aggregate. The results showed that CO_2 strengthening can improve the physical and mechanical properties of recycled concrete. The apparent density and bulk density of recycled coarse aggregate strengthened by CO_2 increased by 1.2%, the water absorption decreased by 27.3%, and the crushing index decreased by 10.5%. Gao Yueqing et al.[17] showed that the carbonation rate and CO_2 absorption rate of CO_2 reinforced recycled aggregate increased with the increase of water-cement ratio of recycled aggregate. CO_2 strengthening significantly reduced the alkalinity and water absorption of recycled aggregate, and significantly improved the compressive strength and chloride ion permeability of recycled aggregate concrete.

3.3 Solution soaking

Xu Hongbo [18] found that water glass strengthening has a significant reduction effect on the crushing index and water absorption of recycled coarse aggregate. Cheng Haili et al.[19] showed that the strength of recycled aggregate concrete was significantly improved by soaking recycled aggregate in 5% water glass solution for 1h. Yang Feihua [20] obtained that the compressive strength of recycled concrete can be greatly improved when the recycled concrete aggregate is soaked in 3% water glass solution at room temperature for 1h.

Song et al. [21] obtained that polyaluminum sulfate has a certain strengthening effect on the properties of recycled aggregate and recycled concrete, and the concentration of 20% polyaluminum sulfate has the best strengthening effect on recycled concrete. Su Wenyang [22] used the recycled coarse aggregate soaked in polymer to reduce the crushing value, water absorption and bulk density by 32.7%, 13.4% and 7.1%, respectively. And the apparent density and porosity increased by 2.9% and 2.6%, respectively.

Wu et al. [23] soaked two different recycled aggregates into 10% PVA solution for modification. The results showed that 10% PVA solution can effectively improve the self-defects of recycled aggregate, and greatly reduced the water absorption of recycled aggregate and improved the strength of recycled aggregate. PVA modification had a certain degree of improvement on the compressive strength of recycled concrete in the middle and late stages, and the improvement effect of splitting tensile strength was not obvious.

4. Microbial enhancement method

Microbial mineralization deposition technology (MICP) is to use the calcium carbonate induced deposition function of some microorganisms in nature to fill the permeable porous medium to improve the pore structure of the material or repair the micro-cracks of the concrete material [24]. Elevant scholars use this technical feature to improve the pore structure of recycled aggregate. While there are few related studies. Hao Xiaohu [25] found that microbial mineralization precipitation can effectively improve the quality and apparent density of recycled aggregate.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202112_7(12).0076

5. Conclusion

(1) Recycled aggregate modification is the main method to solve the poor performance and large discreteness of recycled concrete. However, the current strengthening methods have their own advantages and disadvantages. When selecting a modification method, it should be considered comprehensively from the aspects of economy, environmental protection and convenience.

(2) The existing modification methods are costly and environmentally-friendly. Modification methods can be optimized to reduce costs and reduce environmental pollution.

(3) The evaluation of the strengthening effect mainly focuses on the appearance, water absorption, crushing index and apparent density of the recycled aggregate. And the the workability, usability and durability of recycled concrete should also be concerned. It is suggested to establish quality standard and test method of reinforced recycled aggregate. In addition to the porosity, water absorption and crushing index of recycled aggregate, the mechanical properties of mortar or concrete should also be evaluated.

(4) At present, the domestic construction waste crushing and recycled aggregate processing technology is relatively backward. The development and application of technology and equipment for construction waste recycling should be promoted actively.

References

[1] Li Qiuyi, Li Yunxia, Zhu Chongji, et al. Recycled concrete aggregate strengthening technology research [J]. Concrete, 2006 (01): 74-77.

[2] LI Wengui, LONG Chu, LUO Zhiyu et al. Review on failure mechanism and modification of recycled aggregate concrete [J]. Journal of Architectural and Civil Engineering, 2016, (06): 60-72.

[3] Li Qiuyi, Li Yunxia, Zhu Chongji.Effect of particle shaping on properties of recycled coarse aggregate [J].Material Science and Technology, 2005 (06) : 579-581.

[4] Zhu Yaguang, Han Jiquan, LI Qiuyi, et al. Experimental study on mechanical properties of particle shaping recycled aggregate concrete [J].Journal of Qingdao University of Technology, 2009,30 (04) : 115-118.

[5] Xiao Jianzhuang, Wu Lei, Fan Yuhui. Modification test of recycled coarse aggregate by microwave heating [J]. Concrete, 2012 (07): 55-57.

[6] Su Yan, Gu Song, Chang Xiaolei, et al.Experimental study on heat modified recycled concrete coarse aggregate [J]. China Concrete and Cement Products, 2015 (10): 6-10.

[7] Zhao Haixin, Sun Ying. Experimental study on microwave heating modified recycled aggregate [J]. Bulletin of the Chinese Ceramic Society, 2019, 38 (11): 3518-3523.

[8] Wang Jian, Yu Yao, Li Hao, etc. Experimental study on the performance of recycled coarse aggregate reinforced by microwave heating [J]. Ningxia Engineering Technology, 2021, 20 (02): 144-147.

[9] Ye Zhe. Recycled coarse aggregate modification and its influence on concrete performance [D].Anhui Jianzhu University, 2020.

[10] Yu Kai. Experimental study on mechanical properties of recycled coarse aggregate concrete strengthened by hydrochloric acid [D]. Qingdao University of Technology, 2018.

[11] Wang Jianghao, Geng Ou, Li Fumin. Experiment on the effect of various modification methods of recycled coarse aggregate on the compressive strength of concrete [J].The Journal of Architectural and Civil Engineering, 2016,33 (02) : 91-97.

[12] Tam V, Tam C M, Lekn. Removal of cement mortar remains from recycled aggregate using pre-soaking approaches[J]. Resources Conservation & Recycling, 2007, 50(1): 82-101.

[13] Behfarnia K, Rostami M. An assessment on parameters affecting the carbonation of alkali-activated slag concrete[J]. Journal of Cleaner Production, 2017,157: 1-9.

[14] Shi C, Li Y, Zhang J, et al. Performance enhancement of recycled concrete aggregate review [J]. Journal of Cleaner Production, 2016, 112(Jan.20pt.1): 466-472.

[15] Liang C, Pan B, Ma Z, et al. Utilization of CO2 curing to enhance the properties of recycled aggregate and prepared concrete: A review [J]. Cement and Concrete Composites, 2019, 105: 103446.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202112_7(12).0076

[16] Ying Jingwei, Meng Qiujiang, Xiao Jianzhuang. CO2 strengthening of recycled aggregate and its influence on compressive strength of concrete [J]. Journal of Building Materials, 2017, 20 (02): 277–282.

[17] Gao Yueqing, Pan Bihao, Liang Chaofeng, et al. Characteristics of CO2-Enhanced Recycled Aggregate and Its Effect on Properties of Recycled Concrete [J]. Journal of Civil and Environmental Engineering, 2020: 1-9.

[18] Xu Hongpo. Experimental study on mechanical properties of recycled coarse aggregate concrete strengthened by sodium silicate [D].Qingdao University of Technology, 2018.

[19] Cheng Haili, Wang Caiyan.Study on the strengthening effect of water glass on concrete recycled aggregate [J].New building materials, 2004 (12) : 12-14.

[20] Yang Feihua, Hao Liwei, Cheng Haili. Experimental study on the effect of recycled coarse aggregate of waste concrete modified by sodium silicate on the strength and frost resistance of concrete [J]. Jiang Xi Jian Cai, 2015 (12): 43-45.

[21] Song Xuefeng, Bai Chao. Effect of chemical strengthening agent on properties of recycled aggregate and recycled concrete [J]. Bulletin of the Chinese Ceramic Society, 2019, 38 (06): 1748-1754.

[22] Su Wenyang. Study on mechanical properties of polymer modified recycled aggregate concrete based on meso-scale [D]. Hefei University of Technology, 2020.

[23] Wu Suyao, Zong Xiang. Effect of PVA modified recycled aggregate on basic mechanical properties of recycled concrete [J]. Journal of Yangtze University (Natural Science Edition), 2019,16 (04) : 115-118.

[24] Zhu Yaguang, Wu Chunran, Wu Yankai, et al.Research progress in microbial mineralization deposition to improve the performance of recycled aggregate [J].Concrete, 2018 (07) : 88-92.

[25] Hao Xiaohu, Zhang Jiaguang, Li Zhu, et al. Experimental study on the modification of recycled aggregate based on the mineralization and deposition of Bacillus cereus [J].Concrete, 2018 (10) : 70-73.