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Review of Recycled Aggregate Pervious Concrete Research

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Abstract: *Recycled aggregate concrete soil emerged in Europe, America, Japan and other countries, can effectively solve the problem of urban road surface water, and the effective recycling of waste resources can contribute to the dual-carbon goals. Through reviewing and studying the relevant papers in the past 10 years, we summarize the relevant research results of the present preparation, properties and applications, and point out the defects of its strength and service life, so as to put forward some suggestions for the future development.*

Keywords: *recycled aggregate, Pervious concrete, construction waste*

1. Introduction

With the development of China's industrialization and modernization, the industrial level has been improving and the building construction capacity has been increasing, and the accompanying construction waste has also been produced continuously. 2020 China's total production of construction waste exceeded 3 billion tons, usually used in simple landfills, open piles and other ways of disposal, the effective recycling rate is extremely low, resulting in a serious waste of resources and environmental pollution[1-2]. The pile of construction waste encroaches on the limited land area, and the resources can not be effectively recycled, affecting the surrounding environment, reasonable recycling of construction waste is imperative.

On the other hand, as China's urbanization process is becoming more and more rapid, the impermeable area of the ground is increasing, which often leads to urban flooding, heat island effect and other problems, since 2014 the state has vigorously implemented the construction of sponge cities, promoting the development of new concrete materials.

2. Manuscript Preparation

2.1. Current Research Status of Recycled Aggregate Pervious Aggregate Concrete

Concrete is a widely used building material in the current construction materials, which is diverse and can be categorized into different types according to different contents. Porous concrete, also known as macroporous concrete and pervious concrete, is a porous structure with macro voids formed by mixing cement, coarse aggregate and water, without fine aggregate or with a small amount of fine aggregate, after setting and hardening.

In 1852, the United Kingdom prepared the first concrete without fine aggregate in the process of building construction, that is, permeable concrete. In the 1970s, the United States widely used permeable concrete in parking lots and secondary roads, and Japan was the first country to start exploring permeable paving, and in order to solve the problem of subsidence of foundations and other problems, it implemented the "rainwater infiltration plan" in the early 1980s. Japan was the first country to start exploring permeable pavement. China's research on pervious concrete started in 1993, in 1995 to master the pervious concrete related technology.

Researchers at home and abroad to explore the optimization of permeable concrete treatment, such as scholars use the slurry package theory method and draw on the compressible stacking model, such as mixing ratio research, and later in order to sustainable development and enhance the performance, mixed with a certain amount of fly ash and a certain proportion of steel slag, etc[3].

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2.2. Recycled aggregate

Recycled aggregate refers to the concrete, mortar, stone or masonry from construction waste that is crushed, screened and mixed in a certain proportion, thus replacing natural aggregate, which can increase the efficient use of waste resources. Compared with natural aggregates, recycled aggregates have high porosity, many surface cracks, low strength and other defects. Often have to use certain measures to ensure its strength.

2.3. Recycled Aggregate Pervious Concrete

Recycled aggregate pervious concrete is pervious concrete in which some or all of the large aggregates are replaced by recycled aggregates, and is characterized by a rough surface layer, high water permeability, and good ductility.

2.3.1. Recycled Aggregate Pervious Concrete Preparation and Proportioning

Xue Dongjie, Liu Ronggui et al [4] used C50 waste concrete as a test block and cement paste externally mixed with silica fume to strengthen recycled aggregate, and utilized the volumetric method for the proportion design, while testing the feasibility of determining the flow degree of cementitious material paste to select the molding method (Figure 1). Zhu Jinchun et al[5] chose five kinds of recycled aggregate parameter programs (0.25%, 50%, 75% and 100%) to study the reasonable parameter values using orthogonal test method, and the result was that 30% of recycled aggregate doping was the most reasonable when compressive strength was used as a single evaluation index. Gong Ping[6] used the volumetric method to conduct proportioning tests, and concluded that under the condition of 28d pervious concrete, the optimal porosity is 15%, the optimal aggregate modification coefficient is 97%, and the water-cement ratio is optimal when it is 0.35-0.4. ALIABDO[7] concluded that 10% silica fume mixing can significantly improve the strength of RAPC. Adding styrene butadiene latex had a positive effect on the strength of RAPC.

Zhang Jingbo[8] pretreated the recycled aggregate by cement coated slurry method and calcium acrylate monomer solution immersion method, which greatly improved the performance of permeable concrete. Shen Qianzhou[9] selected three kinds of recycled aggregates, such as waste concrete, waste mortar, and waste road bricks, and found that waste concrete is a good recycled aggregate after test, and silica fume can be used to effectively improve the strength of recycled aggregate concrete, but it will reduce the permeability coefficient. Tang Haifeng[10] studied four molding methods of pervious concrete. After the study, it is concluded that the best way is hand vibration plate vibration production. Chen Shoukai l[11] prepared recycled pervious concrete with waste concrete as coarse aggregate and waste glass particles as fine aggregate, and found that waste glass particles can promote cement hydration, improve the pore structure of recycled aggregate pervious concrete, and improve its strength properties more substantially through multi-scale tests.

Figure 1: Concrete test block

2.3.2. Investigation of the properties of recycled aggregate pervious concrete

Zhang Gaobo and Gong Ping[12] analyzed the effect of the size of recycled aggregate particle size on permeable concrete, and determined that the optimal aggregate particle diameter is 10-16 mm: 16-20 mm, and the optimal volume sand rate is 5% (Figure 2). Wang Junqiang[13] concluded through experiments that the water-cement ratio is suitable 0.25-0.35, mineral admixture 15%-30%, target porosity 15%-25%, permeability coefficient 3.2mm/s, recycled aggregate particle size 5-20mm, and stacked porosity ≤45%.

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Figure 2: Recycled aggregate particle size 10-16mm and 16-20mm.

Guo Lei[14] concluded through tests that recycled aggregate permeable concrete compared with natural aggregate permeable concrete: compressive strength is large, tensile strength is small, mass loss rate is high, durability performance is low, and fibers can significantly improve abrasion resistance and tensile and compressive strength. Yang Lixiang[15] derived from orthogonal tests that the permeable concrete with recycled aggregate The primary and secondary order of factors affecting compressive strength and permeability performance is: design porosity > aggregate gradation > sand rate > water-cement ratio, and the electric furnace slag can significantly improve the mechanical properties and abrasion resistance of permeable concrete.

2.3.3. Recycled Aggregate Pervious Concrete Applications

Xia Qun[16] concluded that the comprehensive performance of road permeable concrete is best when the water-cement ratio, vibration time, and molding pressure are 0.31, 10s, and 2.5 MPa, respectively. Xia Weidong[17] summarized the application of recycled aggregate concrete in "sponge city", which has significant effect in river, wet pond, rainwater wetland, etc., and the ultrafine aggregate can also be used for greening planting in lawn green space. Xiao Liguang[18] explored the application of recycled aggregate concrete in sponge cities, proposed that the actual application is prone to clogging, the percolation rate will be reduced by more than 60% after 1-2 years, and basically lose the drainage performance after 4 years. Zhao Jia[19] investigated the application of recycled aggregate pervious concrete in berms by testing its performance with hemispherical recycled brick aggregate porous concrete, which can be used as a kind of unitary component for berms to consolidate the soil and prepared with FeSO4 solution to promote plant growth (Figure 3).

Figure 3: Hemispherical test block

2.3.4. Summary of the current state of research

Overall recycled aggregate pervious concrete can be made from construction waste and is inexpensive, and its performance can be greatly improved by various admixtures, making it a positive choice for future urban ground design. However, its strength needs to be improved, its service life is limited, and it needs to be cleared of clogging material periodically. Future research may be carried out in the following aspects:

The performance of recycled aggregate pervious concrete is affected by multiple factors, stress, freezing, etc. will make it deteriorate and unusable, how to solve the reduced performance under the action of multiple factors deserves attention. After a certain amount of use will be clogging phenomenon, making the permeability greatly reduced, need to clean up the clogged pavement, the future should strengthen the pore space field related research, to enhance its service life. At present, recycled aggregate permeable concrete is mainly used for the road surface with small passage pressure, and the strength research is relatively insufficient, and its use can be expanded after improving its strength.

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3. Recycled Aggregate Pervious Concrete Development

3.1. Best developed countries

The research on pervious concrete has been carried out in various developed countries since the 1990s, with the most mature research in the United States, Japan and Europe.

The United States has 28 states allow recycled aggregate used in highway construction, of which 15 developed a recycled aggregate related specifications, the military has also increased the proportion of recycled aggregate in the construction of the use of engineering, in addition to the introduction of the "Superfund Act" to protect the development of recycled aggregate permeable concrete, the use of microwave technology can be 100% recycling of the old asphalt concrete road surface material.

Japan due to the small size of the country, the utilization rate of resources are very high, in 1991 on the development of "recycled aggregate and recycled aggregate concrete use of norms" to protect its development, in 1997 and the development of the "Resource Reuse Promotion Act," which makes the use of resources is very detailed, in 1998, the reuse rate of construction waste has reached 56%. With the deepening of research and the continuous improvement of technology, the Japanese Industrial Standards (JIS) issued standards for recycled aggregates and RAC for load-bearing structures.

3.2. Development of the best institutions

In 1904 as the American Cement Users Association, the American Concrete Institute ACI is a nonprofit technical research group and standards development organization that is the world's leading authority on concrete technology.

Its global guide for recycled aggregate concrete, ACI CRC 18.517: Guideline Development for Use of Recycled Concrete Aggregates in New Concrete, was developed in 2019, discussing standards requirements around the world (Figure 4), and in the text, multiple experimental Research and review is conducted in the paper to establish a database including: RCA replacement level, effective water-cement ratio, maximum aggregate particle size, aggregate absorption capacity, slump, etc., and recommendations are made for the future development of recycled aggregate concrete in the world.

Requirement	Class I	Class II	Class III
Water absorption	<3%	<5%	<8%
Apparent density	>2450 kg/m^3	>2350 kg/m^3	>2250 kg/m^3
Porosity	<47%	<50%	<53%
Content of clay by mass	<1%	<2%	<3%
Content of clay lumps by mass	<0.5%	<0.7%	<1.0%
Content of elongated and flaky particles	<10%		
Content of organic	Standard		
Sulfide and sulphate by mass	<2%		
Chloride by mass	<0.06%		
Other impurities	<1%		
Mass loss	<5%	<10%	<15%
Crushing Index	<12%	<20%	<30%

Figure 4: RCA particle requirements set by us

3.3. Researchers

Professor Qin Weizhu of Tsinghua University is an expert in construction materials in China, and has long been devoted to the research of concrete. In 2008, Prof. Qin prepared a microporous permeable material using fine sand dense accumulation as matrix and epoxy resin as binder, which can meet the paving requirements of pedestrian walkway, and the permeable structure has been greatly optimized. At the 2nd East China Sea Forum in 2022, it was proposed that an effective way to develop "low-carbon concrete" in China could be to use a large amount of industrial waste residue as active fine admixture instead of a large amount of clinker, so that the amount of cement can be reduced.Prof. Jiang Zhengwu, a professor of Tongji University, has studied the void ratio and strength of permeable concrete by the ratio of bone ash, water/cement ratio and mixing process, and proposed that water reducing agent, silica fume and polymer emulsion can improve the water permeability. For China's dual-carbon target proposed, focusing on the optimization of cement, replacing aggregates with solid waste, strengthening recycling, is also the embodiment of low-carbon concrete.China University of Mining and Technology, Prof. Wang

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Dongmin, once studied the different composite mineral admixtures on the long-term performance of concrete, slag and fly ash, steel slag, etc. can effectively improve the performance of concrete. For the future development of concrete, it is hoped that low-carbon cementitious materials, excellent admixtures, with fully compliant solid waste (aluminum silicate-based) instead of sand and gravel to create low-carbon concrete.Prof. Chen Shoukai of North China University of Water Conservancy and Hydropower has conducted in-depth research on the strength of recycled aggregate concrete, aggregate mixing ratios, water-cement ratios and so on in the past five years. Research on construction waste recycled concrete pore characteristics of the evaluation method and detection of construction waste recycled aggregate water absorption characteristics of the device and test method, etc. and obtained a patent.

4. Prospects and applications

In summary, there are quite a lot of research results on recycled aggregate pervious concrete at home and abroad, and a lot of research has been made on the preparation, proportioning, properties and other methods of pervious concrete, and some experience has been accumulated in practical application. Generally speaking, in terms of material formulation, there are fewer studies on the relevant technology for the preparation of pervious concrete using recycled aggregates from construction waste, and there are more comparative studies on the incorporation of recycled aggregates and natural aggregates; in terms of properties, the compressive strength, tensile strength, and durability of pervious concrete with recycled aggregates have been involved; in terms of material application, pervious concrete is mostly applied to the roads and squares in the construction of sponge cities, parking lots, and less application in other fields; in the experimental research, it is mostly shown as a simulation test, and there are less field tests in the actual project, which can be combined with the actual test in the future to solve the technical problems specifically existing in the practical engineering.

References

[1] WEI Yingshuo, JI Guoqiang, HU Liqun. A review of research on recycling and reuse of construction waste [J]. Silicate Bulletin,2019,38(09):2842-2846.
[2] ZHANG Junhui, DING Le, ZHANG Anshun. A review on the application of recycled construction waste in roadbed engineering[J].Chinese Journal of Highway,2021,34(10):135-154.
[3] Liang Luming. Preparation and performance of highly permeable fly ash concrete[J]. Comprehensive utilization of fly ash,2018(05):58-62.
[4] XUE Dongjie, LIU Ronggui, XU Rongjin, HE Zhengqing. Preparation and basic properties of permeable concrete with recycled aggregates[J]. Concrete,2013(06):124-127.
[5] Jinchun Zhu, Dingyi Yang, Xiaohuan Zhang et al. Research on the problem of recycled aggregate admixture in recycled pervious concrete[J]. Concrete and Cement Products,2014,(10):6-11.
[6] GONG Ping, ZHANG Gaobo, ZHOU Yu. Optimized selection of key parameters for volumetric method proportioning design of recycled aggregate pervious concrete[J]. Comprehensive utilization of fly ash, 2014(04):3-5.
[7] ALIABDO A A,ABD ELOMATY A E M,FAWZY A M. Experimental investigation on permeability indices and strength of modified pervious concrete with recycled concrete aggregate [J].Construction and Building Materials,2018,193:105-127.
[8] ZHANG Jingbo, LU Lu, SONG Peng. Effect of recycled aggregate pretreatment on the performance of pervious concrete[J].Shandong Chemical Industry,2019,48(01):41-42+45.
[9] SHEN Qianzhou, DING Huazhu, SHU Yangbo, SHEN Yinjie, HE Dingming. Study on the performance ofpermeable concrete with different recycled aggregates[J].Sichuan Building Materials, 2022, 48(01):15-16.
[10] TANG Haifeng, CUI Haonan, CHENG Ziyu et al. Experimental study on the effect of molding method on the performance of permeable concrete with different aggregates[J].Renewable Resources and Circular Economy,2022,15(03):33-36.
[11] CHEN Shoukai, LIU Yang, ZHAO Yunpeng et al. Modification of recycled aggregate pervious concrete by waste glass particles[J].Journal of Building Materials,2023,26(01):37-44.
[12] ZHANG Gaobo,GONG Ping. Effects of aggregate particle size and volumetric sand rate on the performance of recycled aggregate pervious concrete[J].Sichuan Building Materials,2014,40(03):35-36+38.
[13] Wang Junqiang. Experimental study on strength and water permeability performance of recycled aggregate permeable concrete[J].Structural Engineer,.2015,31(04):167-171.
[14] GUO Lei, LIU Siyuan, CHEN Shoukai et al. Research on mechanical properties water permeability

ISSN 2663-1563 Vol. 6, Issue 2: 1-6, DOI: 10.25236/AJAGE.2024.060201

and abrasion resistance of fiber-modified recycled aggregate pervious concrete [J]. Journal of Agricultural Engineering,2019,35(02):153-160.
[15] YANG Lixiang, HAN Yunting, SONG Xingfu. Research on the influence of multiple factors on the performance of recycled aggregate pervious concrete and its synergistic optimization[J]. New Building Materials, 2020, 47(04):6-9+17.
[16] XIA Qun, XIE Feifei, ZHU Pinghua. Research on molding process of sandless permeable recycled aggregate concrete for roads[J]. Concrete,2016(08):149-151+155.
[17] XIA Weidong, LU Shenlei, YU Liqiang. Application of recycled aggregate from construction waste in sponge city construction [J]. Jiangsu building materials,2016,(04):21-22.
[18] Xiao Liguang, Lin Man. Research on the application of recycled aggregate pervious concrete in sponge cities[J]. Journal of Jilin University of Architecture,2017,34(04):9-12.
[19] ZHAO Jia. Research on alkali reduction and slope protection technology of permeable concrete with recycled brick aggregate [D]. Shandong Agricultural University,2017.