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Abstract. Recycled concrete is a resource utilization technology of building rubbish, which is of great significance to environmental protection and socio-economics. And because prefabricated structure buildings adopt standardized design, factory production, information management, assembly construction and intelligent applications, it can meet the needs of sustainable development. The combination of these two technologies can give full play to the environmental advantages of this structure. This article starts from the three aspects of work performance, mechanical performance and anti-seismic performance, and summarizes the research status and analyzes the feasibility of applying recycled concrete to prefabricated structures to promote the further integration of these two environmentally friendly construction technologies.

1. Introduction

For a long time, the traditional construction industry has been unable to meet the requirements of contemporary sustainable development due to numerous problems such as heavy environmental pollution, high energy consumption, long construction cycles and low production efficiency. Based on this situation, realizing sustainable and healthy development of the construction industry and vigorously developing building assembly technology are extremely important.

In developed countries, prefabricated buildings are relatively mature. By the end of 2018, the prefabricated structure in the United States accounted for 52% of the total concrete structure; Japan's prefabricated technology and management are at the world-leading level, and its prefabricated structure accounts for 78% of the total concrete structure. However, although China's building assembly technology is developing rapidly, it is still in its infancy.

In addition, high-speed urbanization has brought rapid consumption of building materials, which has caused serious ecological damage. Economic development is increasingly restricted by the environment and resources. As per the latest plan of the Ministry of Housing and Urban-Rural Development, China will build 0.3 zillion square meters of new dwellings by 2020. By then, the production of domestic construction waste will peak and is expected to exceed 3 billion tons.

Nowadays, China generally adopts landfill and open-air disposal methods for construction rubbish, which occupies cultivated land and also causes serious waste of resources and environmental pollution. How to cope with and utilize it properly has become the focus of government and universities. As shown in figure 1, recycled aggregate is a processed product of waste concrete and can replace natural aggregate for concrete production. Obviously, the proper utilization of recycled concrete can not only greatly reduce the adverse impact of waste concrete landfill on our living conditions, but reduce the exploitation of natural resources.

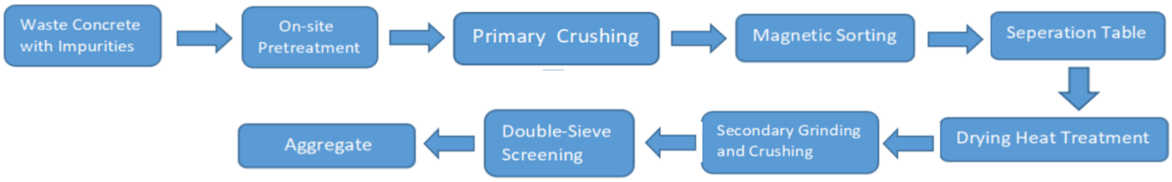

Figure 1. Flow chart of recycled aggregate production.

Therefore, the use of recycled concrete in prefabricated buildings can give a full play to their energy saving and emission reduction. This article will explore the feasibility of prefabricated recycled concrete structure from the three aspects: working performance, mechanical properties and anti-seismic property, and provide theoretical basis and suggestions for the better application of recycled aggregate concrete to prefabricated buildings.

2. Working performance

Recycled concrete's workability means that the concrete mixture is easy to operate and can obtain the performances of uniform quality and compact molding. It is divided into three aspects: fluidity, water retention and cohesiveness. Researchers at home and abroad have found through various tests that the workability of recycled concrete is not equal to that of ordinary concrete. However, by improving the workability of recycled concrete through effective measures, it can finally meet the production requirements of prefabricated components.

2.1. Fluidity

The fluidity of recycled concrete refers to the performance of the concrete mixture under its own weight or external force, which can fill the model uniformly and densely.

J Ma et al. [1] and M J Zhang et al. [2] finalized experimental research on the basic properties of recycled concrete by using slump cylinder method to check the fluidity of freshly mixed recycled concrete. It illustrated that under the same water-cement ratio, the slump of concrete gradually decreased, as the replacement rate of recycled coarse aggregate increased. The latter found that when the replacement ratio was 100%, the slump was relatively reduced.

Therefore, because the recycled coarse aggregate has an upper rate of water absorption than natural coarse aggregate, plenty of mixing water is sucked in during the mixing process, which results in a decrease in the actual mixing water and affects the results of the above studies. X P Liu [3] proved that when the aggregate replacement rate and the water-cement ratio were high, increasing the sand rate could effectively improve the workability of the mixture. Y Qiu et al.[4] obtained reasonable results through experiments which the sand ratio could improve the cohesiveness and fluidity of recycled concrete, and was conducive to the performance of its workability. C Hui et al. [5] tested the effects of different sand ratios on the slump of recycled concrete through experiments. The test results showed that for RC-30, even if the maximum slump could reach more than 120mm at a sand rate of 0.40, it could meet the requirement of Technical Specification for Concrete Pumping Construction (JGJ / T 10-2011) that the slump should not be less than 100mm. However, the transportation will still cause slump loss of recycled concrete, so the slump value, when finally arriving at the site, may be lower than the requirement specified by the code. However, compared with cast-in-situ concrete, the internal vibrator, the external vibrator, the surface vibrator and the shaking table can be used in combination in the process of making the prefabricated components, which is more conducive to concrete compaction. At the same time, the precast component can avoid the loss of slump value during transportation. Hence, recycled concrete is more applicable for prefabricated components.

2.2. Water retention and cohesiveness
Water retention and cohesiveness are two indicators having an important influence on the durability of recycled concrete and both reflect the stability of the concrete mixture.

J Ma et al. [1] found through experiments that when the replacement rate of the recycled aggregate was fifty percent, the freshly mixed concrete had good cohesiveness without any bleeding, but there was a phenomenon of aggregate exposure. J J Zheng et al. [6] and S M Jia et al. [7] believed that the rough surface of the recycled aggregate could increase the friction between the various components of the concrete premixing and make the water retention and cohesiveness of the recycled concrete premix better. Therefore, the water retention and cohesiveness of recycled concrete are better than natural coarse aggregate concrete.

2.3. Summary
The replacement rate of recycled aggregate has a significant effect on the fluidity of recycled concrete, which can be improved by increasing the sand rate. With the replacement rate of RCA increasing, the water retention and cohesiveness of freshly mixed recycled concrete are getting better and better, which leads to higher strength of recycled concrete. Secondly, the RCA has a large water absorption rate. After the raw materials are mixed with water, the recycled coarse aggregate absorbs a lot of water, which reduces the actual water-cement ratio of the cement slurry. They can effectually enhance the strength of recycled concrete and have a positive impact on improving the quality of concrete, making it suitable for the production of prefabricated components.

3. Mechanical properties
Mechanical properties play a crucial role in the field of research on recycled concrete. This chapter will analyze compression resistance, tensile properties and fracture resistance to provide theoretical basis and proposals for further study on recycled concrete.

3.1. Compression resistance
The ability of compression resistance is important for the application of concrete. Factors such as the natures of recycled aggregates, the replacement rate of recycled aggregates, and the water-cement ratio will affect the compressive strength of recycled concrete.[8]

C J Zega et al. [9] studied the effects of different properties of recycled aggregates on the compressive strength of recycled concrete. Three types of recycled aggregates were used: granite, siliceous sandstone, and quartzite. For concrete, when the water-cement ratio was 0.7, the compressive strength of the concrete prepared from the quartzite recycled aggregate was 15% and 35% higher than that of the concrete prepared from the granite recycled aggregate and the siliceous sandstone recycled aggregate respectively, and when the water-cement ratio was 0.4 and 0.7, the compressive strength of the concrete prepared from the quartzite recycled aggregate of was the highest, which could reach 45 MPa and 23 MPa respectively.

J Z Xiao et al. [10] showed that for recycled concrete with different water-cement ratios, as the replacement rate of recycled aggregates increased, the compressive strength of recycled concrete decreased. When the replacement rate of recycled aggregate was fifty percent, the compressive strength of recycled concrete was the largest, which could reach 37 MPa. Y X Guo et al. [11] showed that the replacement rate of recycled aggregates and the compressive strength of recycled concrete were linear. With the replacement rate increasing, the compressive strength would decline. They fit the linear relationship curve between the compressive strength and the replacement rate of recycled concrete with different amounts of cementitious materials and found that if the quality of the recycled aggregate was better, the impact of the replacement rate of the recycled aggregate on the compressive strength of the recycled concrete would be smaller.

As for the effect of water-cement ratio, Z G Guo et al. [12] found the results with different replacement rates. As the water-cement ratio increased, the compressive strength of the recycled concrete decreased. J Li et al. [13] found that the impacts of water-cement ratio, recycled aggregate content and fly ash content on the compressive strength of recycled concrete through orthogonal experiments. The result was that for 28 d compressive strength of recycled concrete, the water-cement ratio was the most significant influence factor, followed by the amount of recycled aggregate and fly ash.

3.2. Tensile properties

Concrete is a brittle material with low tensile strength. In some projects, the magnitude of concrete tensile strength is a prerequisite to directly judge whether the concrete is eligible. Recycled concrete has lower tensile properties than ordinary concrete due to internal cracks, holes, and adhesive mortar, so it is especially important to improve its tensile properties.

Tensile properties of recycled concrete can be improved by adding additives to the recycled concrete. J J Tang et al. [14] investigated the impact of the number of steel fiber spreading layers and the amount on the tensile strength of recycled concrete. The quantity of designed layers were 1-7 and the content of steel fiber was 1.0 kg/m^2, 1.5 kg/m^2 and 2.0 kg/m^2 respectively. The result showed that with the increase in the number of steel fiber layers and the amount of additives, its tensile properties had been greatly improved, up to 4.95MPa. A A Elhakam et al. [15] found the results of reaction of recycled aggregates immersed in water for 30 days, mixed with 10% silica fume, and two-stage mixing on recycled concrete. Among them, the treatment with water immersion for 30 days made the tensile strength of recycled concrete 20% higher than that without immersion. It is because the further hydration of the remaining unhydrated cement particles in the recycled aggregate; the addition of silica fume can improve the interface transition zone of the recycled aggregate, and the 28-day tensile strength of the recycled concrete was 16% higher than that without silica fume. J F Huo et al. [16] found that when the content of steel fiber was 2 percent, the splitting tensile strength was the highest; and when the polypropylene fiber content was 0.8 kg/m^3, the splitting tensile strength could reach a maximum of 3.9MPa.

3.3. Fracture resistance

Fracture resistance is the index evaluating if the recycled concrete will be damaged by bending load, which is also called the flexural strength. D Y Gao et al. [17] showed the result that the mix of steel-polyolefin hybrid fibers observably enhanced the flexural performance of recycled concrete, mainly because the bridging effect of hybrid fibers could resist crack propagation. D S Tang et al. [18] discussed the influencing factors of the flexural properties of recycled concrete through orthogonal experiments. He found the higher the amount of steel fiber was, the greater the flexural strength was and the higher the amount of rubber may cause degradation of its flexural strength. H Katkhuda et al. [19] used the chopped basalt fiber (BF) and acid treatment to increase the flexural performance of recycled concrete. The results showed that with the rise in the content of basalt fiber, the 28-day flexural strength of concrete prepared from recycled aggregates had continued to increase. In addition, the flexural strength of concrete prepared from acid-treated recycled aggregates was slightly better than that of untreated recycled aggregates. C Zhou et al. [20] analyzed the effect of the replacement rate of recycled aggregate on the flexural strength, and found that the recycled concrete with the 30% recycled aggregate replacement rate had the smallest flexural strength, and the recycled concrete with the 80% replacement rate had the highest flexural strength which could reach 6.39 MPa.

3.4. Summary

In summary, the effect of water-cement ratio on the compressive performance of recycled concrete is greater than the amount of recycled aggregate, and by adding basalt fiber and silica fume, the compressive performance of recycled concrete can be improved or surpass that of ordinary concrete. Adding basalt fiber, steel fiber, polypropylene fiber, superplasticizer, silica fume and other materials to the recycled aggregate can increase the tensile performance of the recycled concrete effectively and meet the basic production requirements of concrete; In actual engineering, you can also add synthetic fibers such as steel fibers, steel-polyolefin hybrid fibers, and chopped basalt fibers to rationally control the water-cement ratio of recycled concrete and appropriately increase the replacement rate of recycled aggregates (cement slurry, ball milling), so the flexural resistance of recycled concrete can be improved, making it suitable for the manufacture of prefabricated components. production of prefabricated components.

4. Anti-seismic performance

In addition to normal design loads, recycled concrete structures need to withstand dynamic loads such as earthquakes, explosions, impacts. In order to better design and analyze the structure, the anti-seismic performance of recycled concrete materials must be discussed and studied.

For the shear wall structure, W L Cao et al. [21] completed low-cycle repeated horizontal loading tests on recycled concrete high-shear walls and recycled concrete low-shear walls. The test results showed that the anti-seismic performance of the recycled concrete low-shear wall with a shear span ratio of 1.0 was similar to that of ordinary concrete low-shear wall. The change of the replacement ratio of recycled coarse aggregate had little effect on the seismic performance of shear walls; and the anti-seismic performance of recycled concrete shear walls with concealed braces was significantly improved. In another test, W L Cao et al. [22] compared the anti-seismic performance of fabricated recycled concrete shear wall structures with different shear span ratios and axial compression ratios. The results showed that they were close and even higher than the calculated value of the bearing capacity of the cast-in-situ concrete shear wall specified in GB 50010-2010 "*Code for Design of Concrete Structures*" [23]. Compared with cast-in-situ shear walls, semi-assembled recycled concrete shear walls with lower axial compression ratios had better energy dissipation capacity, and their overall anti-seismic performance was basically the same. And their elastoplastic deformation capacity met the requirements of current codes. At the same time, C W Liu et al. [24] compared the anti-seismic performance of ordinary concrete and recycled concrete shear walls with assembled single-row reinforcement, and the results showed that under the low cycle reciprocating loads, the failure mode and mechanical performance were consistent, which proved that the prefabricated components could be made of recycled concrete.

As for the frame structure, although there is a comprehensive research on the performance of recycled concrete materials in China, there are few reports on the research and evaluation of the overall anti-seismic performance of recycled concrete frame structures. Based on this situation, J Z Xiao et al. [25] made a deep analysis of the anti-seismic performance of recycled concrete frames based on shaking table tests and concluded that the acceleration, displacement response and seismic effects of recycled concrete frame structures in the test were similar to those of ordinary concrete frame structures. After several earthquake tests, although the recycled concrete frame structure was severely damaged, it still did not collapse after the rare earthquake of 9 degrees, which indicated that the recycled concrete frame structure had good collapse resistance.

To sum up, when recycled concrete is used in prefabricated building components, its anti-seismic performance is similar to that of ordinary concrete prefabricated components. For semi-assembled buildings, under the action of earthquake, the failure mode and mechanical performance of the recycled concrete shear wall structure and ordinary concrete shear wall structure are consistent. And the low axial pressure ratio of the semi-assembled recycled concrete shear wall has better energy saving capacity, which is in line with the sustainable development goals of energy conservation and carbon reduction in buildings which are currently being implemented in China. At the same time, its elastoplastic deformation capacity can meet the requirements of current codes, and its bearing capacity is similar to that of ordinary concrete shear walls. Therefore, prefabricated components can be made from recycled concrete.

5. Conclusion

This paper mainly expounds the work performance, mechanical properties, and anti-seismic performance of recycled concrete, and analyzes Chinese and foreign research progress in this field. Most researchers believe that the working performance of recycled concrete materials and components are inferior to ordinary concrete to varying degrees, but it can be improved through appropriate measures (such as adding appropriate amounts of suitable admixtures, particle shaping, improving construction technology or maintenance conditions, etc.) to make its performance comparable to or even better than ordinary concrete.

The application of recycled concrete can essentially cope with the problem of treatment of waste concrete. It not only reduces the environmental pollution, but saves natural aggregate resources. And it is able to satisfy the requirements of sustainable development and is one of the main ways to develop green concrete. At the same time, recycled concrete with a appropriate mix percentage design can also basically meet the performance requirements of ordinary concrete, and it is feasible to be used in civil engineering. Thus, it is suggested that the government can issue corresponding policy support, and the state can formulate laws and regulations to promote the sustainable and healthy development of recycled concrete.

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