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Review Article

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Review of Recycled Concrete Research

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Abstract Construction waste are the mainly raw materials for the preparation of recycled concrete. Improving the utilization efficiency of recycled concrete can reduce the project construction cost, reduce the amount of existing construction waste, reduce the environmental pollution, and promote the green and healthy development of urban construction.

Keywords construction waste; recycled concrete; research status

1. Introduction

China's economic level is rapidly increasing since reform and opening up, people's living standards continue to improve, put forward the higher request to housing. Therefore, the construction industry has been booming. More and more construction waste such as waste concrete is produced at the same time. The stacking of a large number of construction waste not only brings inconvenience to people's lives, but also causes serious damage to the environment. Therefore, during the period of China's 13th five-year plan, China has proposed the green and ecological development idea to promote the disposal of abandoned concrete and other construction wastes. Recycled concrete is the waste concrete after crushing, cleaning and grading as coarse aggregate, and the new concrete formed by adding cement, water and additive additives [1]. The new development concept of the 13th five-year plan provides a good opportunity for the application and development of recycled concrete.

China's production of commercial concrete was 2.56 billion cubic meters in 2019. The production of commercial concrete in the first half of the year also had 1.15 billion cubic meters despite the outbreak of epidemic in the first half of 2020 [2]. Such a huge output of concrete leads to a huge consumption of coarse and fine aggregate such as sand and stone, which not only leads to a large consumption of resources, but also causes certain damage to the environment. The demand for demolition and reconstruction of municipal engineering is increasing due to the continuous progress of society, so a large number of waste concrete and other construction wastes are generated at the same time. Therefore, it is very important to continue to strengthen the research on recycled concrete.

2. China's research status

There are still lots of research achievements in China though the research on reclaimed concrete started late. Chinese scholars' research mainly focused on the influence of recycled aggregate substitution rate on performance, mix design, strengthening and modification, and micro research.

2.1 Study on the influence of recycled aggregate substitution rate on the performance

Xiao et al [3] studied the influence of different replacement rates of recycled aggregate on the mechanical properties of recycled concrete. The research results show that the strength of recycled concrete decreases by 20% when recycled coarse aggregate is used as aggregate, and 15-40% when recycled fine aggregate is used as aggregate under the condition of single replacement of recycled aggregate. The recycled coarse aggregate has a greater influence on the strength of recycled concrete under the condition of double substitution of recycled aggregate. Nian and Luo studied the influence of the replacement rate of recycled aggregate on the flexural fatigue performance of recycled concrete. The results show that the fatigue life of recycled concrete will be reduced with the increase of recycled aggregates. And the fatigue life of recycled concrete fell by around 50% than ordinary concrete when aggregate are all made of recycled aggregate [4]. Sun and Gu studied the influence of water binder ratio and recycled aggregate replacement rate on the performance of recycled concrete. The results show that the replacement rate of recycled aggregate has a great influence on recycled concrete. The compressive strength of recycled concrete is significantly lower than that of ordinary concrete when the replacement rate of recycled aggregate is 30% and 50% [5].

2.2 Mix design of recycled concrete

Qiao et al [6] designed orthogonal experiments with five factors and four levels in order to find out the optimal mixing ratio of ceramic recycled concrete, taking ceramic powder, ceramic particles, recycled fine aggregate, fly ash and silica fume as aggregate and admixture. The results show that the strength and thermal conductivity of ceramic recycled concrete are optimal when the ceramic powder content is 10%, ceramic particle content is 20%, recycled fine aggregate content is 40%, fly ash content is 15% and silica fume content is 5%. Zhang et al [7] studied the influence of mix design methods such as equal mortar method and equal mass substitution method on carbon emission of recycled concrete. The results show that the carbon emission of recycled concrete prepared by the same amount of mortar is less. And there is little difference between the carbon emission of recycled aggregate replacement rate of 50% and 70% when the same amount of mortar is used to prepare recycled concrete. Chen et al [8] found that recycled concrete can achieve the strength grade of C35 and slump of 180mm when the mixture ratio of recycled concrete is cement: recycled coarse aggregate with small particle size: sand: high efficiency water reducer: water is 1:1.81:3.75:0.005:0.6. Zhang et al [9] used the orthogonal test method to study the mix design of recycled concrete. And the results show that the best mix ratio of recycled concrete is water cement ratio of 0.41, recycled coarse aggregate content of 20% and recycled fine aggregate content of 15%.

2.3 Reinforcement and modification of recycled concrete

Many scholars adopt some modification and add measures can be better applied to engineering practice because of the recycled concrete has some natural defects. Adding fiber is a concrete measure to modify and strengthen recycled concrete. Hou [10] summarized the mechanical properties of fiber reinforced recycled concrete in the world at this stage. Sheng [11] designed an orthogonal test with three factors and three levels based on the content of steel fiber, fly ash and recycled coarse aggregate to study the influence of three factors on the mechanical properties of recycled concrete, and use the extreme difference analysis and variance analysis to analyze the test data, a non-linear regression model for calculation of these factors. The results show that fiber and fly ash content will have an effect on the mechanical properties of recycled concrete, recycled coarse aggregate content on the mechanical properties of recycled concrete is affected. The mechanical properties of recycled concrete is increased with the increase of steel fiber content, but the mechanical properties of recycled concrete can reduce with the increase of the content of fly ash. Moreover, adding steel fiber can increase the use of recycled coarse aggregate and consume more recycled coarse aggregate. Yang et al [12] conducted an experimental study on the mechanical properties of the modified recycled concrete modified with fibers. The results show that the tensile properties of recycled concrete can be significantly improved after adding fibers. Yang and Zhou studied the

improvement of mechanical properties of recycled concrete with glass powder. The results show that the later mechanical properties of recycled concrete are improved though the early mechanical properties of recycled concrete are reduced by adding an appropriate amount of glass powder, and the 90d compressive strength, splitting strength and elastic modulus of recycled concrete with 10% glass powder are higher than those of ordinary recycled concrete [13].

2.4 Micro study of recycled concrete

He et al [14] studied the microstructure of steel fiber recycled concrete with recycled aggregate substitution rate of 0, 50% and 100%. The results show that the interface transition zone between natural aggregate and recycled aggregate and cement paste is relatively obvious. However, the hardened cement paste of natural aggregate concrete is more compact and has fewer internal voids compared with the hardened cement paste of recycled concrete. Xu et al [15] used SEM analysis and other methods to quantitatively analyze the interface transition zone of recycled concrete. Gao et al [16] used SEM and EDS to study the influence of ion erosion on the micro morphology of the multi interface transition zone of recycled concrete.

3. Other countries' research status

The research on recycled concrete by other countries' scholars is mainly focused on the performance, mix design, modification and enhancement.

3.1 Performance research of recycled concrete

Lu et al [17] simulated the influence of acid rain on the frost resistance of recycled concrete. And their research results show that the frost resistance of recycled concrete would be greatly weakened under the influence of acid rain with high acidity, and the frost resistance of recycled concrete would decline with the continuous extension of the soaking time of acid rain. Mycherla studied the effect of silica fume on the mechanical properties of recycled concrete. The results show that the permeability of recycled concrete prepared with 25% recycled aggregate replacement rate increased by 6.5%. The strength of concrete specimens prepared with 25% recycled aggregate and 10% fine aggregate is 17% and 40% higher than that without fine aggregate and 20% fine aggregate respectively. The compressive strength of recycled concrete is increased by nearly 56% and the flexural strength is increased by 33% when the content of silica fume in concrete is 8%-16% [18].

3.2 Reinforcement and modification of recycled concrete

Khaleel [19] studied metakaolin modified recycled concrete containing recycled steel fiber. The results show that the slump value of recycled concrete is lower than that of ordinary concrete, and the use of metakaolin and recycled steel fiber will slightly reduce the construction workability of recycled concrete. The use of metakaolin can improve the compressive strength of recycled concrete. The compressive strength of recycled concrete is 6% higher than that of ordinary concrete when metakaolin and recycled steel fibers with different contents are used at the same time, but the flexural strength and splitting tensile strength of recycled concrete are lower than that of ordinary concrete. Sameh et al [20] studied the use of polymers to improve the performance of recycled concrete. The results show that the use of styrene butadiene rubber can improve the compressive strength and tensile strength of recycled concrete with different recycled aggregate content, and the recycled concrete with 50% replacement rate of recycled bone shows better performance when the content of styrene butadiene rubber is 1.5%. It is found that the tensile strength has also been improved when the content of polypropylene fiber is 1%.

3.3 Mix design of recycled concrete

Mehran et al [21] found that the compressive strength of recycled concrete continuously decreased with the increase of recycled aggregate content, and found that the substitution of fine aggregate had less impact on compressive strength than that of coarse aggregate. Recycled concrete with 30% fine aggregate content showed the best performance in the test so it can be used as the best mix and the use of steel fibers greatly improves the tensile and elastic strength of recycled concrete. Marco et al [22] proposed a new mix design method for recycled concrete, which can be used to predict the compressive strength of recycled concrete by only considering the water absorption capacity, so as to determine the "quality" of recycled concrete.

4. Problems of Recycled Concrete

Many studies have shown that recycled concrete has characteristics such as water absorption, low strength and large porosity compared with ordinary concrete. These characteristics will lead to many problems in recycled concrete. The intensity is the first problem. It is shown that the compressive strength of recycled concrete will decrease with the increase of aggregate content, and the compressive strength of recycled concrete can be effectively improved by adding modified materials such as fibers through the research of many scholars on the mechanical properties of recycled concrete. Another problem of recycled concrete is that the shrinkage rate of recycled concrete is large. Because recycled concrete is mainly prepared from recycled aggregate, but the recycled aggregate has the characteristics of large porosity, and it is easy to produce more cracks in the crushing process, resulting in the disadvantage of large water absorption. The water absorption will increase the shrinkage rate of recycled concrete after water loss, resulting in a large number of cracks, and seriously affect the durability of recycled concrete. Therefore, aggregate, mix design, concrete curing environment and method, cement variety and other factors should be comprehensively considered in the preparation process of recycled concrete.

5. Conclusion

Many scholars have done a lot of research on recycled concrete, and there have been relatively complete research results in improving the mechanical properties and mix design of recycled concrete. Future research can be further expanded in microstructure, curing conditions and durability. A complete research theory of recycled concrete can not only make recycled concrete better applied in future engineering practice, but also alleviate the huge resource and environmental pressure brought by construction waste.

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