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All Solid Waste Concrete Status Analysis

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Abstract

Driven by global sustainable development and China's "dual-carbon" goal, all-solid-waste concrete has attracted much attention as a green building material. It is made from steel slag, slag and other industrial solid waste as the main raw materials through the optimization of the mix ratio, and the hydration process relies on the steel slag component to provide an alkaline environment, which promotes the hydration of slag to generate a dense structure. Technologically, solid waste-based cementitious materials and aggregate processing technology continues to develop, such as ultrafine grinding, composite exciters and crushing and shaping processes to enhance the material performance. In terms of performance, the early strength is low but continues to grow in the late stage, the 28-day strength can reach 47.4MPa, excellent resistance to chloride ions and freeze-thaw resistance, and weaker resistance to carbonization. Currently facing challenges such as limited utilization of low-activity solid waste, high cost, and insufficient market awareness, it is necessary to strengthen technical research and development, reduce costs, and improve standards to promote its development.

Keywords

Solid waste, concrete, concrete properties.

1. Introduction

In the context of global advocacy of sustainable development and China's efforts to promote the "dual-carbon" goal, the green transformation of the construction industry is imminent [1]. Concrete, as the most used building material in the construction field, faces the double challenge of resource shortage and environmental pressure in its traditional production method. The all-solid-waste concrete technology came into being, which uses industrial solid waste (e.g., steel slag, slag, fly ash, desulfurization gypsum, etc.) as the main raw material and replaces the traditional cement and aggregate to prepare concrete, which provides a new direction for solving the resource and environmental problems in the construction industry [2], and has received extensive attention and research in recent years.

2. Technical principles and key technological developments

2.1. Technical Principles

Waste concrete is made from solid waste-based cementitious materials (e.g., steel slag, slag, desulfurization gypsum, etc.) and tailings waste rock aggregate by optimizing the mix ratio and green production methods [3]. Its hydration process mainly relies on C_3S and C_2S in steel slag, and these components take the lead in hydration to provide an alkaline environment for the system, which promotes the further hydration of slag and generates hydration products such as calcovanadate and hydrated calcium silicate, which result in a denser concrete structure. For example, in some studies, it was found that tricalcium silicate (C_3S) in steel slag reacts rapidly in the early stage of hydration, releasing calcium ions and hydroxide ions, which enhances the alkalinity of the system and stimulates the potential activity of the slag, which induces the

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vitreous constituents in the slag to undergo a hydration reaction to form more hydration products to fill up the internal pores of the concrete, thus improving the strength and durability of the concrete.

2.2. Key technological developments

Solid waste-based gelling material preparation technology: In recent years, the activity and performance stability of solid waste-based gelling materials have been continuously improved by means of mechanical grinding and chemical excitation. For example, the use of ultrafine grinding technology can increase the specific surface area of solid waste particles and improve their reactivity [4]; through the research and development of composite chemical exciters, the hydration process of solid waste-based gelling materials is precisely regulated to better meet different engineering needs. For example, in some engineering practice, using multiple solid waste composite preparation of cementitious materials, through the optimization of the exciter formula, its early strength and late strength growth can achieve good results, to meet the requirements of rapid construction and long-term structural performance.

Solid Waste Aggregate Processing Technology: For tailings, waste rock and other solid waste aggregates, a series of processing techniques such as crushing, screening and shaping have been developed to improve the quality and applicability of aggregates. For example, through advanced crushing equipment and shaping process, the particle shape and grading of solid waste aggregates can be improved to make it closer to the performance of natural aggregates, thus improving the working performance and mechanical properties of concrete. In some areas of the concrete mixing plant, the finely processed tailings aggregate is used to produce concrete, which has good compatibility and compressive strength to meet the corresponding engineering standards.

3. Performance

The early strength of all-solid waste concrete is low, but the compressive strength continues to increase with age [2]. This is because its hydration products continue to generate and fill the pores in the later stage, making the concrete structure more dense and the strength can be continuously improved [5].

Xu Bing et al [7] carried out an innovative attempt in a shore protection project in Shanghai, adding solid waste such as steel slag powder instead of mineral powder, converter drum steel slag instead of sand, and electric furnace steel slag instead of crushed stone into concrete. After testing, 28 days of age, the mechanical properties and durability of the concrete is not inferior to ordinary concrete, and compressive and flexural strength has been significantly improved, to achieve the performance optimization and solid waste utilization of the dual objectives.

Yang Chen et al [8] showed that with the increase in the amount of steel slag, the compressive strength of concrete increased, while the split tensile strength decreased. The hydration activity and surface properties of steel slag played an important role in improving the mechanical properties of concrete, but reduced the strength due to its poor volume stability. The results of the study showed that the replacement of natural coarse aggregate by steel slag can significantly improve the compressive and cracking strength of concrete at no more than 50%. However, all-solid waste concrete is weak against carbonation. This is mainly due to the composition and microstructural characteristics of its hydration products, which make the alkali reserve inside the concrete relatively low, and in the carbon dioxide environment, it is more likely to undergo carbonation reaction, which reduces the alkalinity of the concrete and affects the stability of the passivation film of the steel reinforcement [6].

Jin Jing et al [9] found experimentally that after many freeze-thaw cycles, as the fineness of steel slag decreases continuously from 23.1 μm to 4.2 μm, the concrete its frost resistance is gradually enhanced, and the carbonation depth decreases.

Huang Lijie et al [10] experimental research found that the steel slag dosage in the range of 20%-30%, its resistance to chloride salt erosion is significantly stronger than the general standard concrete, indicating that steel slag has a positive effect on the resistance of concrete to chloride salt erosion. From the perspective of permeability grading, the chloride permeability of steel slag concrete belongs to a relatively low level. The test also showed that under the condition of 20%-30% of steel slag and the same water-cement ratio, the carbonation resistance of steel slag-added concrete was slightly worse than that of ordinary standard concrete, but the difference was not significant; however, with the increase in the amount of steel slag, the carbonation resistance was improved, which was manifested in the reduction of carbonation depth, but the increase was small.

Zhu Leilei [11] through the 100mm × 100mm × 50mm different dosage of steel slag concrete cubic specimens, the resistance to chlorine ion penetration performance research, its results show that with the increase of steel slag substitution rate of its flux gradually decreased, steel slag dosage of more than 50%, the concrete resistance to chlorine ions performance is better.

4. Challenges and issues

4.1. Technical aspects

The limited admixture of some low-activity solid wastes in all-solid-waste concrete affects the large-scale elimination of solid wastes and further cost reductions. For example, solid wastes such as coal gangue and some tailings, due to their low activity, can lead to problems such as slow development of concrete strength and deterioration of workability when mixed in large quantities in concrete. The performance stability of all solid waste concrete still needs to be improved. Due to the wide range of solid waste sources, the composition is complex, and there are differences in the chemical composition and physical properties of different batches of solid waste, which can easily lead to fluctuations in the quality of all-solid-waste concrete products, affecting its wide application in the project.

4.2. Cost level

Although all-solid waste concrete has certain advantages in raw material costs, its production process has higher pretreatment costs, technology development costs, etc., resulting in the comprehensive cost compared with traditional concrete, the advantage is not obvious enough. Especially in some smaller-scale production enterprises, the cost problem is more prominent due to the inability to realize large-scale production, which limits the market competitiveness of all-solid waste concrete.

5. Conclusion and outlook.

As a green and environmentally friendly building material, all-solid waste concrete has already achieved certain results in terms of technical principles, performance performance, application practice and industrial development. Its advantages in energy saving and emission reduction, resource utilization and environmental protection are in line with the trend of sustainable development of the construction industry and have a broad development prospect. However, at present, all-solid waste concrete still faces many challenges in terms of technology, cost and market promotion. In the future, it is necessary to further strengthen technical research and development, break through the bottleneck of low-activity solid waste utilization technology, and improve the stability of product performance; reduce costs through large-scale production and technological innovation; strengthen market promotion and publicity, improve market awareness and trust, and improve the industry standard system, in order to promote the healthy and rapid development of the all-solid-waste concrete industry, and to make a greater contribution to the green transformation and sustainable development of the construction industry.

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