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Research Review on the Durability of Activated Coal Gangue Concrete

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Abstract

In the 21st century, environmental protection has become one of the focuses of human attention. While pursuing economic development, humans are also making efforts to find a point of convergence between environmental protection and resource utilization. The preparation of concrete from activated industrial waste coal gangue not only alleviates environmental pollution but also promotes green building, demonstrating good economic benefits. This article adopts a literature survey method to comprehensively review the durability of activated coal gangue concrete, focusing on its resistance to chloride ion penetration, corrosion resistance, and carbonation resistance. Furthermore, the durability of activated coal gangue concrete is summarized, and the development trend of high-content activated coal gangue concrete is prospected.

Keywords

Activated Coal Gangue; Concrete; Durability.

1. Preface

Coal gangue, as a waste product of coal mining and processing in China, has a low comprehensive utilization rate. In the 21st century, environmental protection has become one of the focuses of human attention. While pursuing economic development, human beings are also making efforts to find a point of convergence between economic growth, environmental protection, and resource utilization. Long-term storage of coal gangue occupies land, pollutes the atmosphere and groundwater, and causes serious three-dimensional pollution to the environment, posing a threat to people's lives and property safety. Nowadays, the country is focusing on the rapid emergence of new competitive models with low emissions, low energy consumption, and low pollution. The focus of society has shifted from the previous blind pursuit of economic growth to a low-carbon economy[1]. The reasonable recycling and reuse of coal gangue is a response to this new lifestyle. At the same time, with the continuous development of the economy, the construction industry is also making progress. Green building has become a trend in this era, and the concept of integrating with nature and reusing resources is gradually infiltrating into the construction industry. The reasonable application of coal gangue in the construction industry has great significance in today's society.

This article summarizes the research progress and achievements of scholars at home and abroad in this field by summarizing relevant literature research. It summarizes the chloride ion permeability resistance and corrosion resistance of activated coal gangue concrete, as well as its carbonation resistance. Furthermore, it summarizes the durability of activated coal gangue concrete and looks forward to the development trend of high-dosage activated coal gangue concrete.

2. Chloride Ion Permeability Resistance

Concrete is a porous, multi-phase, and non-uniform composite material widely used in building structures and infrastructure. In specific environments, chloride ions penetrate into the concrete and

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cause corrosion of steel bars. Xu Rongsheng[2] indicated that chloride ions are one of the main reasons affecting the durability of concrete. Adding an appropriate amount of activated coal gangue to concrete can effectively improve its chloride ion permeability resistance.

Zhou Shuangxi et al.[3] improved the activity of coal gangue by mechanical-thermal composite activation. The experiment found that activated coal gangue under specific conditions, when mixed into concrete, can significantly improve its chloride ion permeability resistance. Especially when the mixing amount of activated coal gangue is 30%, the water-binder ratio is 0.4, and the sand ratio is 0.35, the chloride ion diffusion coefficient of the concrete reaches its minimum, demonstrating excellent chloride ion resistance.

Mo Jinchuan et al.[4] measured the chloride ion content of concrete test blocks with different coal gangue mixing amounts using the ion-selective electrode method and analyzed the impact of coal gangue mixing on the chloride ion diffusion coefficient of concrete. The study found that coal gangue treated with 3-hour ball milling and 800℃ calcination has a compressive strength evaluation coefficient of 80.9%, indicating high activity. When the mixing amount of this activated coal gangue is 30%, the water-binder ratio is 0.4, and the sand ratio is 0.35, the chloride ion diffusion coefficient of the concrete reaches a minimum of 6.3564μm2/s. This suggests that activated coal gangue can effectively improve the chloride ion permeability resistance of concrete under appropriate mixing amounts.

Ma Hongqiang et al.[5] evaluated test specimens using a rapid chloride ion permeability test. The experiment showed that first, the cavities existing at the bonding interface between coal gangue and cementitious materials are unfavorable for the compressive strength and durability of concrete. However, these cavities are beneficial for the chloride ion permeability resistance of concrete. This is because coal gangue has the ability to solidify chloride ions, and as the mixing amount of coal gangue coarse aggregate increases, its ability to solidify chloride ions also increases. Second, calcination treatment can increase the activity of coal gangue. During calcination, the crystalline components in coal gangue decompose, generating SiO2 and Al2O3 with pozzolanic activity. These active components can participate in secondary hydration reactions, generating C-S-H gel and C-A-S-H gel, etc., making the internal structure of concrete denser. However, although the activity of calcined coal gangue increases, due to the loose structure of coal gangue during calcination, its durability does not show a significant advantage.

Song Xiaojun et al.[6] used activated coal gangue as a cement admixture to prepare concrete with strength grades of C30 and C60, and set ordinary concrete as a control group. Chloride ion permeability tests were used to characterize the permeability resistance. The experiment measured that after 6 hours of electrification, the electrical conductivity of ordinary concrete with both strength grades was higher than that of coal gangue concrete. This is because the incorporation of activated coal gangue replaces some of the cement, reducing the components susceptible to corrosion in the hydration products, such as calcium hydroxide. This helps reduce the content of components susceptible to chloride ion corrosion in concrete. The pozzolanic effect of coal gangue consumes a portion of calcium hydroxide, generating stable hydrated calcium silicate gel. The formation of this gel improves the composition of hydration products and enhances the durability of concrete. Additionally, the fine particles in coal gangue exert a filling effect, making the cement paste structure and interface denser. This dense structure reduces pore size and blocks potential permeability paths, thereby improving the pore structure of concrete and enhancing its permeability resistance. Therefore, both C30 and C60 concrete mixed with activated coal gangue exhibit better chloride ion permeability resistance than ordinary concrete.

In summary, the chloride ion permeability resistance of activated coal gangue concrete is significantly improved, but when the mixing amount of coal gangue exceeds a certain peak, it can instead inhibit chloride ion permeability resistance. Additionally, treated calcined coal gangue exhibits superior chloride ion permeability resistance. However, in practical applications, it is necessary to consider

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reasonable water-binder ratios, silica fume mixing amounts, and coal gangue mixing amounts to effectively maximize the chloride ion permeability resistance of coal gangue concrete.

3. Corrosion Resistance

Concrete, as a commonly used building material, has good strength and durability. However, due to the existence of various chemicals in the environment, concrete may be chemically corroded during long-term use. Therefore, it is very important to study the corrosion resistance of coal gangue concrete specimens.

Liu Shi[7] et al. made three groups of coal gangue concrete with different mixing amounts (0%, 30%, and 60% respectively), which were immersed in solutions with pH values of 3, 5, and 7 for 30 days. Then they measured the water absorption performance and strength changes of the specimens in an acidic environment to evaluate the durability of activated coal gangue concrete. The experiment showed that the water absorption performance of activated coal gangue concrete was significantly affected in an acidic environment. As the pH value of the solution decreased, the cumulative water absorption height, initial water absorption rate, and second-stage water absorption rate of the specimens all showed significant increases. This indicates that the acidic environment has a negative impact on the capillary water absorption characteristics of concrete. The experiment also observed the influence of the acidic environment on the strength of activated coal gangue concrete. Under the long-term corrosion of acidic solutions, the strength of concrete may decrease to a certain extent. This may be due to chemical reactions between acidic solutions and some components in concrete, leading to the destruction of the concrete structure. It shows that coal gangue concrete is greatly affected by its durability in acidic solutions.

Zhang Liming[8] et al. tested the sulfate resistance of the samples according to the "Test Method for Sulfate Resistance of Cement" (GB/T 749-2008) and concluded that the volume stability of concrete mixed with calcined coal gangue LC3 cement deteriorated, but its sulfate resistance improved. With the decrease of the water-binder ratio, the deterioration of volume stability will weaken, and the sulfate resistance will increase.

In summary, the corrosion resistance of coal gangue concrete is affected by various factors, including the pH value of the acidic environment and the mixing amount of coal gangue. In an acidic environment, as the mixing amount of coal gangue increases, the acid resistance of its concrete gradually decreases. The corrosion resistance of coal gangue concrete is a complex issue affected by various factors. In practical applications, it is necessary to select appropriate coal gangue mixing amounts and concrete proportions based on specific use environments and requirements to improve its corrosion resistance. At the same time, it is also necessary to strengthen research and exploration on the corrosion resistance of coal gangue concrete, providing more theoretical support and practical guidance for its application in actual engineering to ensure optimal concrete durability.

4. Carbonation Resistance

Carbonation of concrete refers to the chemical reaction between calcium hydroxide, a product of cement hydration within concrete, and carbon dioxide in the air under certain humidity conditions, which results in the formation of calcium carbonate and water. This process leads to a decrease in the alkalinity of concrete, thereby eliminating the protective effect of the strongly alkaline environment of concrete on steel reinforcement, resulting in corrosion and expansion of the steel reinforcement. In severe cases, it can cause cracks along the longitudinal direction of the reinforcement in the concrete protective layer, leading to spalling and seriously affecting the mechanical properties and durability of reinforced concrete structures. Therefore, improving the carbonation resistance of concrete is crucial for ensuring the long-term performance and effectiveness of engineering projects.

Li Yongjing et al.[9] explored the relationship between the gas permeability coefficient and age of coal gangue coarse aggregate concrete. The experimental results showed that the gas permeability coefficient of coal gangue aggregate concrete decreases as the age increases, and this decrease is

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faster in the early stages and relatively slower in the later stages. This indicates that as the age increases, the density of coal gangue concrete gradually improves, thereby reducing the possibility of gas infiltration, which is beneficial for improving its carbonation resistance.

Li Qingwen et al.[10] studied the variation law of relative humidity on the carbonation depth of coal gangue concrete through rapid carbonation tests. Based on the test results after 7 days of curing in a rapid carbonation chamber, there is a negative correlation between relative humidity and carbonation depth. This means that as the relative humidity increases, the carbonation depth of activated coal gangue concrete will decrease accordingly. This negative correlation is particularly evident within the range of relative humidity from 40% to 80%. In the same curing temperature environment, when the relative humidity is within the range of 40% to 50%, the impact of relative humidity on carbonation depth is more significant. However, as the relative humidity further increases, its impact on carbonation depth gradually weakens, and the decreasing trend of carbonation depth also tends to flatten out.

In summary, the carbonation resistance of coal gangue concrete is affected by various factors. Reasonable calcination of coal gangue, adjustment of the external environment and curing age, selection of appropriate water-cement ratio and coal gangue content can effectively reduce the carbonation depth of concrete, thereby improving its durability and service life. This conclusion is of great significance for guiding the use and maintenance of activated coal gangue concrete in practical engineering projects.

5. Conclusion and Prospect

(1) The resistance to chloride ion penetration of activated coal gangue concrete is significantly improved, but when the mixing amount of coal gangue exceeds the peak value, it will instead suppress the resistance to chloride ion penetration.

(2) The corrosion resistance of coal gangue concrete is affected by various factors, including the pH value of the acidic environment and the mixing amount of coal gangue. In practical engineering, the environment should be taken into account.

(3) The carbonation depth of coal gangue concrete is positively correlated with the percentage of coal gangue and curing time, and negatively correlated with the relative humidity in the curing environment.

(4) The research on activated coal gangue concrete will develop towards higher mixing amounts and better performance. On the one hand, by improving activation technology and enhancing the activity of coal gangue, it can play a greater role in concrete. On the other hand, by optimizing the concrete ratio and preparation process, various properties of activated coal gangue concrete can be improved to better meet the practical application requirements.

(5) With the concept of green building and sustainable development deeply rooted in people's hearts, activated coal gangue concrete, as an environmentally friendly and economical building material, will be more widely used. We look forward to seeing activated coal gangue concrete play a greater role in the construction industry in the future, making greater contributions to China's economic development and environmental protection.

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