

A Review of Mechanical Properties of Activated Coal Gangue

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Abstract

Coal gangue as an industrial waste produced in the process of coal mining and processing in China, according to statistics, the accumulation of coal gangue in China has reached 5 billion t, and the comprehensive utilization rate is low. The activation of coal gangue to replace the aggregate component in concrete can not only reduce the accumulation of coal gangue, but also reduce the use of sand and gravel in industry, which has good economic benefits. The article adopts literature survey method to review the mechanical properties of activated gangue concrete, elaborate the optimal calcination temperature of activated gangue, the effect on the compressive strength of concrete, and the internal mechanism of activated gangue concrete, and summarize the research of domestic scholars on activated gangue concrete.

Keywords

Activated Gangue; Compressive Strength; Internal Mechanism.

1. Preface

At present, the cumulative emissions of coal gangue have reached more than 5 billion t, is China's largest emissions of mine solid waste, and the current comprehensive utilization rate is low [1]. At the same time, The massive accumulation of coal gangue not only occupies valuable land resources, but also leads to serious environmental pollution problems, and may even induce geological disasters such as collapse and debris flow, posing a threat to people's life and property safety [2]. In recent years, with the rapid development of the national economy, green and sustainable development of ecological low-carbon strategic concepts continue to carry out and practice, so how to use coal gangue and other solid waste materials efficiently and environmentally has become an urgent problem to be solved [3].

This paper summarizes the literature research of activated coal gangue concrete at home and abroad in this research field by summarizing the relevant literature research, summarized the optimum calcination temperature of coal gangue for thermal activation, summarizes the effect of different dosage of gangue on the compressive strength of concrete, and the internal hydration mechanism and pore structure of activated coal gangue concrete affecting the strength of concrete are further analyzed, and summarizes the research results of activated gangue concrete in China.

2. The Best Activation Temperature of Gangue

The main chemical composition of gangue is SiO_2 and Al_2O_3 , the nature of its own instability, activity is low, but through chemical activation, thermal activation, and mechanical activation and other ways to stimulate its potential active substances. Thermal activation technology can make the surface of gangue aggregate generate SiO_2 and Al_2O_3 with volcanic ash activity, the active substances can be with the cement hydration product $\text{Ca}(\text{OH})_2$ secondary hydration reaction, so that the aggregate and the cement paste is more dense, reduce the pore space, and is conducive to improving the mechanical properties and durability of the concrete[4] ; Dong Zuocho et al.[5] used X-ray diffraction (XRD), mercury-in-pressure (MIP) method, and the environmental Using X-ray diffraction (XRD), mercury

pressure (MIP) and environmental scanning electron microscopy (SEM) analysis methods, the activity of gangue fine aggregates at different calcination temperatures was investigated, and it was found that the activity of gangue calcined at 700 °C was the best. Zhou Mei et al. [6] determined the best calcination temperature of gangue by studying the higher strength of small fineness unburnt gangue cement at different temperatures, and found that the activity of gangue was improved after high temperature calcination, and the calcination temperature had a greater influence on its activity, and the activity index of gangue from Qing hemen mine was the highest when it was calcined at a temperature of 750°C. Cao Yongdan et al. [7] studied the effect of calcination temperature and fineness on the activity of coal gangue volcanic ash through the test of chemical calcium absorption and mechanical strength of cement sand, and found that the finer the granularity, the higher the activity of coal gangue volcanic ash, and the optimal calcination temperature is about 800 °C. Through SEM image analysis, XRD analysis and mechanical property test on activated coal gangue calcined at different temperatures, Li Qiang [8] et al showed that calcination could activate coal gangue, and the coal gangue calcined to 750°C and held for 2 h had the best activity, and its 28-day compressive strength ratio of cement mortar was 76.6%. The calcination energy can change the 27Al-O and 29Si-O coordination number of coal gangue, and the calcination activity of coal gangue at 750°C is the best. Gao Zhihai et al. [9] analyzed the degree of hydration of heat-activated coal gangue with the help of Ca(OH)₂ residue and the determination of the amount of chemically bonded water, the results show that the degree of hydration reaction of heat-activated coal gangue calcined at a calcination temperature of 750 °C is higher, the Ca(OH)₂ residue is less, and the amount of chemically bonded water is more. Luo Zhongren [10] et al. used X-ray diffraction, scanning electron microscopy analysis, and thermogravimetric analysis to study the thermal activation mechanism of a coal gangue in Shandong. The study showed that when calcined at 600 °C to 800 °C, the phase of the coal gangue sample hardly changed, and it was in the kaolin stage with high activity. At 900 °C, the active substance generated inert coal gangue, but the activity decreased.

According to the research of many domestic scholars, the calcination temperature has a great influence on the activity of coal gangue, and when the calcination temperature is about 750°C, the activity of coal gangue is the highest.

3. Research on the Effect of Activated Gangue on the Mechanical Properties of Concrete

The formation of secondary hydration products of activated gangue and cement can fill the pores of hardened cement and effectively improve the strength of concrete. Zhou Mei et al. [6] investigated the compatibility of calcined gangue powder, fly ash and mineral powder and their effects on the workability and strength of concrete by using additional water consumption, pre-wetting time, sand rate and particle gradation as the varying factors and orthogonal tests. It was found that gangue powder as concrete admixture has improved the workability, early strength and durability of concrete mixes. Li Jian et al. [11] through the study of different gangue admixture on the compressive strength of concrete, found that for C30 and C40 concrete, when the replacement rate of gangue is less than 50%, the compressive strength of gangue concrete does not drop much, but when the replacement rate of gangue is more than 50%, the compressive strength of concrete will happen to drop substantially. Li Xiaoling [12] et al. through the gangue by different proportions of equal amount of replacement of ordinary gravel after the mechanical properties as well as durability performance, found that the gangue on the concrete in the early stage of the impact is small, the later stage of the impact is more obvious. Shen Haichang [13] research gangue to replace the natural coarse aggregate in concrete compressive strength, found that the gangue to replace the natural coarse aggregate is not conducive to the development of concrete strength in the late stage, for the early stage of the strength of the impact is not obvious.

Through the above research, it can be seen that the activated gangue dosage of 30% below the minimum impact on the mechanical properties of concrete, dosage of 30% to 50% of the mechanical

properties of concrete has a small impact on the mechanical properties of concrete, dosage of more than 50% of the concrete strength will be reduced significantly. The reason is that the internal structure of gangue is loose and porous. And the gangue dosage is too large will form a strong mortar wrapped weak aggregate phenomenon, as a coarse aggregate gangue can not play its role, resulting in a reduction in concrete strength. And activated gangue for concrete early compressive strength has less impact, for 28 days and later its influence is greater.

4. Internal Mechanism of Activated Gangue Concrete

Activated gangue contains a large amount of reactive SiO_2 and Al_2O_3 , which have strong secondary hydration reaction activity. The secondary hydration products, hydrated calcium silicate and hydrated calcium aluminate gel, can fill the pores of the cement body, improve the strength of the cement matrix, and then improve the overall strength of concrete. Liu Chaoqun [14] et al. through the study of the effect of activated gangue on the rheological properties, mechanical properties, hydration products and hydration degree of cement, found that the activated gangue blended into cement can effectively reduce the early hydration rate of cement. Tao Qinying et al.[15] used X-ray diffraction (XRD), scanning electron microscope (SEM), energy dispersive spectroscopy (EDS) and microcomputer-controlled compressive folding machine to investigate the compressive strength of the cement mixed with thermal-mechanical composite activated gangue rock, the hydration process, the microstructure of the hydration products, the chemical composition, the morphology and the hydration products of the hydration of the calcium silicate hydrated C-S-H gel. H gel calcium-silicon ratio, it was found that activated gangue blending not only participated in the cement hydration reaction, hydration to generate more low $n(\text{Ca})/n(\text{Si})$ C-S-H, and activated gangue in the activated material will be high sulfur-type hydrated calcium sulfoaluminate (Aft) into a single sulfur-type hydrated calcium sulfoaluminate (AFm), and the activated gangue in the activated material will be high sulfur-type hydrated calcium sulfoaluminate (Aft) into a single sulfur-type hydrated calcium sulfoaluminate (AFm), which led to the optimization of the pore structure.

Comprehensive research of the above scholars, it is found that a large number of activated SiO_2 and Al_2O_3 in the activated gangue react with $\text{Ca}(\text{OH})_2$ in the hydration products of the cement, generating a large number of secondary hydration products, which make up for part of the loss of strength brought about by the reduction of the cement, thus improving the strength of the concrete. At the same time, the activated gangue composite cement system, compared with the pure silicate cement system, generates more C-S-H with reticulation and flocculent structure, which combines the gangue particles and cement particles into a whole, so that the pore space is reduced, the structure is denser, and the pore structure is optimized.

5. Conclusion

- (1). By analyzing and comparing the research of several domestic scholars on the activation degree of calcined coal gangue, the study shows that the activity of coal gangue is highest when the calcination temperature is around 750 °C.
- (2). Through the research of many domestic scholars on the hydration mechanism of activated coal gangue, it is found that the formation of a large number of active SiO_2 and Al_2O_3 of activated coal gangue and cement secondary hydration products can fill the pores of hardened cement, make up for part of the strength loss caused by the reduction of cement, and effectively improve the strength of concrete. The addition of activated coal gangue can generate more C-S-H with network structure and flocculation structure, and optimize the pore structure of activated coal gangue composite cement system.
- (3). The effect of activated coal gangue on the mechanical properties of concrete is minimal when the dosage is below 30%, and the effect of activated coal gangue on the early compressive strength of concrete is minimal.

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