Study on Modification Technology of High Calcium Ash Steel Slag Composite Based on Microstructure Characteristics

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Abstract. By means of physicochemical modification technology, mineral admixture particles adhere to the surface of high calcium ash particles. On the one hand, mineral admixtures play a role of grinding aids, on the other hand, mineral admixtures are uniformly dispersed and closely contacted with high calcium ash particles. It is conducive to the hydration reaction of high calcium ash particles and reduces the most probable pore distribution and porosity. Active calcium oxide has a high content and contains a certain amount of self-hardening minerals. The single modification method of chemical admixtures can not effectively exert the chemical excitation effect of chemical admixtures on the activity of high calcium ash. High calcium ash and steel slag have great potential for utilization in cement concrete, and their full utilization is beneficial to environmental protection, energy saving and obtaining certain economic benefits. High calcium ash and steel slag admixture technology have achieved certain results. However, it is necessary to further study the activity of high calcium ash and steel slag in the fluctuation range of raw materials. And applied to the preparation of high durability gelation blending amount.

1. Introduction
High calcium fly ash is the coal ash obtained by electrostatic precipitation in power plants using calcium-enriched combustion technology. The content of free calcium, periclase and sulfur carbide in high calcium lime is high, which is easy to cause poor stability [1]. At present, physical grinding technology and chemical admixture modification technology are commonly used for the modification of high calcium ash. Single physical grinding only improves the specific surface area, particle size distribution and surface morphology of high calcium ash particles [2]. Active calcium oxide has a high content and contains a certain amount of self-hardening minerals. The single chemical admixture modification method can not effectively exert the chemical excitation effect of chemical admixture on the activity of high calcium ash [3]. The chemical composition of the steel slag is similar to the mineral composition and cement, which determines the gelling properties of the steel slag. When the alkalinity is high, the steel slag contains more C₃S and C₂S and has certain hydraulic activity [4]. A single physical grinding only improves the specific surface area of the high calcium ash particles and the surface morphology of the particles, and a single chemical external additive modification method can not effectively exert the chemical excitation effect of the chemical external admixture on the high calcium ash activity [5]. High calcium ash and steel slag have great potential for utilization in cement concrete, and their full utilization is beneficial to environmental protection, energy saving and obtaining certain...
economic benefits [6].

2. Activity Characteristics of High Calcium Ash, Steel Slag and Composite Minerals

2.1 Activity Characteristics of High Calcium Ash

For concrete materials, coarse aggregate accounts for about 50% of the total volume of concrete, constituting the framework of concrete, so it has an important impact on the micro-structure of concrete. Modern production phases out the process of mixing all cement components such as clinker, gypsum and mixtures together and grinding separately with different components. This provides the conditions for optimizing strength and durability by designing particle size distribution according to the characteristics of different components. In the component design of cement composites, the development direction of research and application is to adopt different mineral combinations. The unique physical shape of the glass microbeads in the high calcium ash can cause the flocculation structure of the cement particles to deflocculate and diffuse the particles, while the smoother round bead-like shell reduces the internal viscosity of the mortar and the friction between the particles [7]. As the amount of high calcium ash increases, the water consumption of the standard consistency is further reduced, and the time to reach initial setting and final setting is delayed. The incorporation of high calcium ash reduces the water consumption of the standard consistency and delays the setting time of the rubber. The chemical composition and specific surface area of high calcium ash and steel slag are shown in Table 1.

| Material         | Chemical composition mass fraction /% | Specific surface area m^2·kg^{-1} |
|------------------|---------------------------------------|----------------------------------|
| High calcium ash | SiO_2: 51.26, Al_2O_3: 11.64, Fe_3O_5: 2.18, CaO: 14.15, MgO: 5.24, SO_3: 1.32 | 459                              |
| Steel slag       | SiO_2: 13.35, Al_2O_3: 5.17, Fe_3O_5: 23.64, CaO: 41.25, MgO: 7.98, SO_3: 1.78 | 451                              |

In practical applications, considering the quality stability, easy accessibility, and scale and simplification of raw materials, multi-component recombination is limited. The combination of dual-component waste minerals is suitable for large-scale production under modern process conditions. With the increase of high calcium ash content, the water consumption of standard consistency is further reduced, and the time to initial setting and final setting is delayed [8]. In the early stage of high calcium ash hydration, only active CaO is involved in hydration. The glass microbeads contained in the high calcium ash have a smooth spherical shape and a dense internal structure, and mainly serve as a filling in the initial stage of hydration. The particle size of the cement affects the hydration activity and bulk density of the particles [9]. Fine particles have high hydration activity, producing effective hydrates earlier, and coarse particles have slow hydration. At the same time, there are few hydrates, even some of them can only exist in cement paste as inert particles. The addition of high calcium ash reduces the water consumption of standard consistency and delays the setting time of the binder. The addition of high calcium ash obviously reduces the standard water consumption of cement. With the increase of the content of high calcium ash, the standard water consumption decreases.

2.2 Activity Characteristics of Steel Slag

With the increase of the content of high calcium ash, the water consumption of standard consistency decreases, and the time of initial setting and final setting is delayed. The solid volume of clinker minerals always increases greatly after hydration, filling the water part in the original system, but the whole system is reduced. The mechanical properties of coal body are not only determined by the content of each organic component in coal body, but also highly correlated with the distribution of each organic...
component and the structural characteristics of primary damage on the organic component. Fine cement particles have high hydration activity and can produce more hydrates. At the same time, the pore volume due to hydration needs to be filled correspondingly. Due to the high surface morphology of the high calcium ash glass beads, the activity is low and the water demand is small. The incorporation of high calcium ash reduces the standard consistency water usage of the cement. Due to the complete surface morphology of the high calcium ash glass microbead particles, the activity is low and the water demand is small. The incorporation of high calcium ash significantly reduces the amount of water used for the thickening of cement. In the early stage of high calcium ash hydration, only active CaO participates in hydration, while the glass microbeads contained in high calcium ash have a spherical outer shape and a dense internal structure. In the early stage of hydration, it mainly acts as a filling, and this filling mainly acts as a barrier to air.

3. Effect of Modified High Calcium Ash on Volume Change of Cement

The addition of high calcium ash reduces the chemical shrinkage of rubber, and with the increase of high calcium ash content, the chemical shrinkage decreases. In addition to active CaO in high calcium ash, most of the other inactive components hardly participate in hydration at the initial stage of hydration. Particularly, the glass bead particles contained in high calcium ash are spherical and smooth outside and compact inside. Because the hydration rate of high calcium ash is lower than that of cement, the total hydration reaction rate of rubber decreases with the addition of high calcium ash, which leads to the decrease of chemical shrinkage rate. To comprehensively analyze and identify the impact tendency of coal seams, it is necessary to understand the distribution characteristics of tissue components in coal. The aggregate gradation curves of different sizes can be seen after reaching the size of the coarse aggregate average particle size and the fineness modulus. The gradation curve does not change much with the increase of the sample size, and tends to be consistent with the aggregate gradation of the whole sample. In the later cooling and cooling process, due to the constraints of the foundation or the old concrete, the tensile stress caused by the tensile stress inside the concrete. The specific surface area of the high calcium ash through the physically modified particles increases, and the ability of the interfacial reaction increases. Thereby the activity is improved, and the enhancement of the hydration reaction ability of the high calcium ash particles can promote the reduction of the porosity and increase the volume reduction caused by the chemical shrinkage [10]. After the physical and chemical modification of the high calcium ash, the early hydration reaction enhances the structural strength and the ability to inhibit the swelling is significantly enhanced. The vitrinite reflectance in different impact-prone coals does not directly reflect the grade of coal impact tendency, while the difference between the maximum reflectivity and the minimum reflectivity of the vitrinite group is related to the coal impact tendency. The statistical results of mean particle size and fineness modulus of coarse aggregate are consistent, which shows that it is reasonable to describe the distribution characteristics of coarse aggregate by mean particle size and fineness modulus of coarse aggregate. The initial setting time of cement is prolonged by decreasing the intensity of reaction in the early stage of induction and prolonging the induction period. If the extension degree is controlled in a certain range, the slump loss of concrete can be reduced.

High calcium ash replaces cement equally and plays the role of micro-aggregate. The volume of mortar in mortar is increased and lubrication is increased, thus improving the workability of mortar. Through outdoor weatherability test, soil corrosiveness test and wet-hot-oxygen stability test, the color difference and mechanical properties of each group of samples were compared and analyzed. To a large extent, the problems of component deformation and failure caused by the difference of sintering shrinkage curve or thermal expansion coefficient between materials of different systems are avoided. The slope of regression line is closer to the square of correlation coefficient and the intercept of regression line is closer, so the prediction result is better. As shown in Table 2 and Figure 1.
Table 2 Comparison of model prediction capabilities

| Model                      | Regression Line | Squared correlation coefficient |
|----------------------------|-----------------|---------------------------------|
| Hybrid model algorithms    | 5.68            | 6.26                            |
| Recursive function         | 8.96            | 13.63                           |

Figure 1 Comparison of model prediction capabilities

With the increase of high calcium ash content, the flexural strength and compressive strength of the rubber sand are reduced. When the high calcium ash content reaches 60%, the strength drop is most obvious. After hydration of clinker minerals, the volume of solid phase is always greatly increased, filling the part of the original system where water is occupied, but the whole system is reduced. High calcium ash replaces cement in an equal amount and can act as a micro-aggregate. It can increase the volume of the slurry in the mortar, and also increase the lubrication, thereby improving the workability of the mortar. In the early stage of high calcium ash hydration, only active CaO is involved in hydration. Because of the pozzolanic reaction of high calcium ash, the early strength develops slowly, and the higher the proportion of high calcium ash in cementitious materials, the lower the strength of mortar. Because the hydration rate of high calcium ash is lower than that of cement, the total hydration reaction rate of rubber materials decreases with the addition of high calcium ash, which leads to the decrease of chemical shrinkage rate. The glass microsphere particles contained in high calcium ash are spherical and smooth on the outside and compact on the inside, which play a major role in filling in the early hydration stage. The second exothermic peak during the acceleration period will be significantly delayed and reduced, thus reducing the hydration heat, which is beneficial to eliminate the cracks caused by thermal stress in cement products.

4. Conclusions
Reducing the amount of cement can reduce the cost of pavement bricks, which has good economic and social benefits. A large number of use of fly ash as industrial waste can obviously improve the various properties of pavement bricks, which has a certain environmental significance. The addition of high calcium ash improves the workability of mortar, reduces the water consumption of standard consistency and delays the initial and final setting time of rubber. The water consumption of standard consistency decreases and the initial setting and final setting time prolongs with the increase of high calcium ash contacting plate. When aggregate volume content is the same, the ratio of geometric representative size to maximum aggregate size of secondary concrete is less than that of primary concrete. Under the condition of replacing half of the cement, the composite of high calcium ash and steel slag has better effect on the flexural and compressive strength of single-doped high-calcium ash, and there is an
optimum blending ratio between high calcium ash and steel slag according to design requirements. The admixture of high calcium ash improves the workability of the rubber sand, reduces the water consumption of the standard consistency, and delays the initial setting time of the rubber material. High calcium ash and steel slag admixture technology have achieved certain results. However, it is necessary to further study the activity of high calcium ash and steel slag in the fluctuation range of raw materials. And applied to the preparation of high durability gelation blending amount.

References
[1] He, Lanlan, Yu, et al. A Novel Method for CO2 Sequestration via Indirect Carbonation of Coal;Fly Ash[J]. Industrial & Engineering Chemistry Research, 2013, 52(43):15138-15145.
[2] Kandasamy S, Shehata M H. The capacity of ternary blends containing slag and high-calcium fly ash to mitigate alkali silica reaction[J]. Cement and Concrete Composites, 2014, 49:92-99.
[3] Wang Q, Yang J, Yan P. Cementitious properties of super-fine steel slag[J]. Powder Technology, 2013, 245:35-39.
[4] Hydration characteristics and environmental friendly performance of a cementitious material composed of calcium silicate slag[J]. Journal of Hazardous Materials, 2016, 306:67-76.
[5] Fan W D, Yang Q W, Guo B, et al. Crystallization mechanism of glass-ceramics prepared from stainless steel slag[J]. Rare Metals, 2018, 37(23):1-8.
[6] Barca C, Troesch, Stéphane, Meyer D, et al. Steel Slag Filters to Upgrade Phosphorus Removal in Constructed Wetlands: Two Years of Field Experiments[J]. Environmental Science & Technology, 2013, 47(1):549-556.
[7] Liu X, Yu G, Xu J, et al. Viscosity fluctuation behaviors of coal ash slags with high content of calcium and low content of silicon[J]. Fuel Processing Technology, 2017, 158(Complete):115-122.
[8] Dri M, Sanna A, Maroto-Valer M M. Mineral carbonation from metal wastes: Effect of solid to liquid ratio on the efficiency and characterization of carbonated products[J]. Applied Energy, 2014, 113:515-523.
[9] Iacobescu R I, Pontikes Y, Kounouri D, et al. Synthesis, characterization and properties of calcium ferroaluminate belite cements produced with electric arc furnace steel slag as raw material[J]. Cement & Concrete Composites, 2013, 44(93):1-8.
[10] Deb P S, Nath P, Sarker P K. The effects of ground granulated blast-furnace slag blending with fly ash and activator content on the workability and strength properties of geopolymer concrete cured at ambient temperature[J]. Materials & Design, 2014, 62:32-39.