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Progress of Straw Ash High Performance Concrete Admixture Application Research

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Abstract. High performance concrete is widely used in research and Engineering, the research progress of high performance concrete admixture is very rapid. The straw ash base contains a large amount of silica, it has certain pozzolanic activity, it is an excellent material to replace some cement and reduce the amount of cement used. However, the residual carbon particles and alkali metals in the straw ash affect the performance of the ash based mixture. In this paper, the effects of pretreatment on straw ash base and the effect of pretreatment on the mechanical properties of concrete were discussed by literature review. The results show that the pretreated straw ash base has better performance, and the prepared high performance concrete also has better properties. Therefore, straw ash as a concrete admixture has broad development areas.

Introduction

The drastic changes in the climate have made humanity impose more stringent standards on environmental protection and climate issues. In particular, the issue of greenhouse gas emissions has become a focus issue. The global greenhouse gas produced annually due to cement production accounts for about 5% of the total global carbon dioxide emissions [1]. Therefore, the search for alternatives to cement to reduce the amount of cement in concrete is currently a hot topic of research.

Relevant studies [2, 3] have shown that biomass straw ash has a certain pozzolanic active ingredient and can be used as a partial replacement of cement for concrete admixture. Under proper conditions, the straw ash produced by incineration will produce certain free silica with higher pozzolanic activity. This is a concrete admixture that can be compared with silica fume [4-6]. Compared with fly ash and blast furnace slag, straw ash has a greater advantage—grain is planted annually, and straw is produced year after year. According to estimates by the UN Food and Agriculture Organization of China, the total amount of straw in China was 940 million tons in 2012, which is the largest producer of straw in the world [7]. Thence, straw ash is used as a concrete admixture to partially replace cement, which not only alleviates the emission of carbon dioxide, but also enables straw to be reused. Therefore, this paper introduces the processing and treatment of straw and straw ash base, and the latest progress in the related research of high-performance concrete admixtures.

Effect of Temperature on Straw Processing

Hui-yuan Li, Si-wei Huang and others conducted a combustion test on corn stover[8]. The results of the combustion are shown in Table 1. From Table 1, the combustion stage can be divided into three stages: (1) The stage of water analysis indicates the evaporation of water in raw materials; (2) The combustion phase of volatile components indicates the combustion of volatile components in the raw materials; (3) The combustion stage of carbon and residual volatile matter indicates that the combustion of the fixed carbon and the previously insufficiently burned combustion is volatilized. When the temperature exceeds 510°C, it shows that the combustible components are basically

burned and the quality no longer changes.

Table 1 Corn stove burning table

Combustion stage	The first stage	The second stage	The third stage	The fourth stage
Temperature	0~120°C	230~340°C	420~510°C	Above 510°C
Specific description	Water evaporation	Volatiles escape	Carbon and residual volatiles escape	After the basic burn, the quality is basically the same

Xiao-xiao Meng and her companions [9] discovered through the pyrolysis experiments of straw that the alkali metal Na and K release characteristics in the straw are similar and Ca and Mg are relatively stable in the pyrolysis process, as shown in Table 2. As shown in Table 2, below 200°C is the drying stage of biomass straw, with a small amount of K precipitated; 300°C- 400°C alkali metal K rapid release, but less than 10% of the total potassium in the straw; The release rate of alkali metal K from 400°C to 600°C becomes slower; nearly 20% is released between 600°C and 800°C; When the temperature reaches 1000°C, the release of alkali metal K has reached 53%.

Table 2 Alkaline metal K precipitation table

Combustion stage	The first stage	The second stage	The third stage	The fourth stage	The fifth stage
Temperature	≤200°C	300~400°C	400~600°C	600~800°C	≥1000°C
Specific description	During the drying stage, a small amount of K precipitates	K quickly released, release ≤10%	K slow release	Large release, close to 20%	K release ≥53%

Temperature Pretreatment Straw Ash

Hong Zhu, Zhi-zhou Chang [10] conducted high-temperature incineration of straw ash and obtained the following results: (1) Temperature has a negative correlation with the content of metals in ash; (2) However, there is a positive correlation between temperature and alkali metal precipitation rate.

Fang Lang, Xiao-xuan Ma and others[11] through burning experiments, the results show that: At the temperature of 550~700°C, the alkali metal precipitation rate in the straw is a rapid growth stage, which is also the main precipitation phase of alkali metal. Above 700°C, the precipitation rate of alkali metals in various straws is a relatively slow period. When the temperature is above 850°C, the alkali metal content of various straw machines tends to be stable, and the rest remains in the semi-coke.

Jagud's research on the precipitation of potassium at different temperatures also found that the process of entering potassium into the gas phase is bounded by 500°C, which can obviously be divided into two stages [12]. In the first stage, the organic potassium bound to the biomass volatilizes. Part of the potassium is resolved due to thermal instability. The second phase is mainly the precipitation of inorganic potassium, which is caused by the vapor pressure causing the potassium to escape into the gas phase and causing the precipitation of potassium. Different combustion temperatures lead to changes in the composition of straw ash. The higher the combustion temperature, the more potassium is present in the form of potassium silicate.

Chemically Pretreated Straw

With the deepening of the research on biomass, more and more researchers are paying attention to the pretreatment of biomass, so that the active ingredients, active substances and other content. The performance of the pretreated biomass ash as an admixture is significantly higher than that of the untreated one.

Guilherme Chagas Cordeiro and his colleagues [13] performed a weak acid treatment of the calcined grassy plants, resulting in a significant increase in activity in hairy ashes. When the blending amount is 20%, the prepared concrete has obvious strength increase; especially the compressive strength is particularly obvious. Feraidon F. Ataie pretreated the corn ash, rice, and wheat with NaOH and dilutes acid, and then after high temperature pyrolysis, it was found that NaOH solution was very poor in treating straw ash [14, 15]. Due to the alkalinity of the NaOH solution during the pretreatment of the straw, not only the $CaCO_3$ crystal phase in the sample but also the Ca, P, and Mg elements in the sample cannot be removed. Ataie conducted a comparative experiment on distilled water and dilute sulphuric acid pretreated corn [6]. It was found that dilute sulfuric acid pretreatment reduced the crystallinity of corn, increased the surface area, and reduced the loss of ash. The prepared concrete has higher compressive strength and better mechanical properties. Although the pretreatment with water washing method can also improve the performance of ash, the water washing method mainly removes the P element in the straw, and the effect is relatively poor with respect to dilute sulfuric acid pretreatment. At a 20% blend, unpretreated ash severely inhibited the hydration of the cement. However, after pretreatment, the early reaction intensity was enhanced and the early hydration performance was enhanced.

Conclusions

From the above discussion, we can draw the following conclusions:

(1) The high-temperature treatment of straw ash slag has good effects except for carbon and alkali metals, but the straw ash has certain slagging properties at high temperatures. The high-temperature treatment causes the alkali metal to overflow in the gas phase, but it is prone to slagging and aggregation;

(2) Pretreatment with chemical methods can effectively separate easily separated components such as K-salt from the sample, and there is better pozzolanic activity in the remaining ash. The performance of the high-performance concrete prepared from the treated straw ash base as an admixture is also more excellent;

(3) When the straw ash is used as a concrete mixture, the pretreated straw ash base ratio is superior to the untreated pozzolanic activity of the sample. The mechanical properties and early hydration performance of the concrete prepared by the pretreated straw ash base have been significantly improved.

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