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Hydration mechanism of Portland cement prepared from stonecoal vanadium slag

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Abstract

This paper presents an objective study on the utilization of stone coal vanadium slag in preparing cement clinker. The hydrates and hydration mechanism of this cement were analyzed and studied by means of the hydration heat analysis, X-ray diffraction (XRD) and the differential thermal gravity (DTG) analysis. The results of experiments show that the hydration mechanism is similar to ordinary Portland cement. The hydration process can be divided into five stages: (I) initial period; (II) induction period; (III) acceleration period; (IV) deceleration period; (V) final period. And the hydrates are basically the same as Portland cement, mainly containing the calcium silicate hydrates (C-S-H), ettringite (AFt), portlandite (CH). It is proved that stone coal vanadium slag can be used as siliceous materials to prepare cement clinker. Furthermore, the addition of fine materials such as the waste and fly ash can accelerate cement hydration, which is the result of giving rise to water-to-cementitious ratio. On the other hand, the fine materials may provide the crystal nucleus for hydrates such as portlandite. Using the waste and fly ash to replace part of clinker can prepare series of cement, whose compositions and physical properties are fully complied with the requirements of national standard, and bring huge ecological and economic benefits.

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*Keywords:*solid waste; stone coal vanadium slag; hydration mechanism; cement clinker

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1. Introduction

With the development of China's mining industry, more and more mineral waste residue is discharged year by year. These solid wastes cause varieties of resources and environmental problem on people's living area. While at the same time, the demands of cement are increasing with the remarkable development of the construction industry. Thus, in recent years, utilization of proper solid waste to prepare cement has become an efficient way to deal with the solid mineral wastes problems[1-7].

Stone coal is a type of inferior anthracite, in which the grade of vanadium is less than 1%. In China, it commonly extracts vanadium resources from stone coal by hydrometallurgical extraction process. In the process, a great deal of solid waste (named "vanadium slag") is inevitably produced. The vanadium slag mainly composites of quartz and silicate minerals. Due to this characteristic, it can be used as siliceous and correction materials to prepare cement clinker. Relevant researches about how to use vanadium slag to prepare cement clinker had been carried out and the qualified cement clinker production had been produced. However, to date, there has been relatively little research conducted on the mechanisms of the production. Especially, the hydration mechanism and property of the cement clinker production are unknown. These mechanisms are very important for the industrial design and practical production. Thus, the purpose of the current research is to characterize the hydration mechanisms of different classes cement prepared from vanadium slag.

2. Experiment

2.1. Raw materials

The cement clinker used in the current research is prepared by self in laboratory. It consists of following steps: (1) stone coal vanadium slag (3-16 wt%) blended with nitric phosphate slag (76-79 wt%) and other various aluminum and iron materials (7-20 wt%); (2) heated at 1350-1450 ℃ and then cooled to room temperature; (3) ground to granularity less than 0.074 mm. The waste used is from mining tailings and fly ash comes from thermal power plants. The mineralogical composition of cement clinker is listed in Table 1, and the chemical composition of materials is listed in Table 2.

Series preliminary experiments about material proportion have been conducted before the research. Among these experiment results, the material ratios of samples complied with the requirements (national standard of China) are picked out. The samples of B, C and D are up to the standard of 52.5#, 42.5# and 32.5# cement. The proportions and physical properties of samples are listed in Table 3.

Table 1 Mineralogical composition of cement clinker

C_3S (%)	C_2S (%)	C_3A (%)	C_4AF (%)
56.62	19.08	7.98	10.23

Table 2 Chemical composition of materials

	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	SO_3 (%)	LOSS (%)	Σ (%)
Clinker	21.56	5.16	3.37	65.01	2.12	0.40	0.27	97.89
Waste	62.31	10.33	6.71	6.83	1.29	0	8.67	96.14
Fly ash	53.17	27.68	6.08	2.88	1.14	0.31	7.52	98.78

2.2. Methods

Cement paste samples were prepared at the w/c (water/cement) of 0.4. The cement paste was placed in a cubic paste mould (20×20×20 mm) and cured for 24h in a certain atmosphere (temperature of 20±2 ℃ and relative humidity of above 90 %). Then, the formed cement cubes were sequentially maintained in water with temperature of 20±1 ℃ for a certain time. After the curing, the cement samples were crushed into small pieces and immersed into