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Influence of active alumina on the hydration process of Portland cement

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Abstract

The work is interested in the study of the hydration process by means of the isothermal calorimetry method. The Portland cement hydration process led to gradual consumption of contained calcium sulfate. This sulfate depletion is observed on the calorimetry curve as a shoulder of main silicate peak. The addition of hydratable alumina to Portland cement was studied in order to determine its influence on hydration process. Experimental results showed the shifted position of this shoulder according to alumina and calcium sulfate content. It was also observed that the overall hydration process was almost unaffected by alumina addition.

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1. Introduction

Hydration of Portland cement is complex process of the reactions which lead to setting and hardening of cement paste. The water addition to cement starts contemporary dissolution reaction of some cement components and formation of the insoluble hydrated products. The main part of Portland cement, alite (C_3S), reacts with water to form the C-S-H gel and portlandite. The same hydration products are also formed during the hydration of other cement component, belite (C_2S). Portland cement is produced by continuous milling of Portland clinker with gypsum. The final properties of cement are strongly influenced by this milling process [1].

Ettringite ($C_6A\bar{S}_3H_{32}$, AFt) as a hydration product, is a result of the reaction between tricalcium aluminate phase

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(C₃A) and gypsum in aqueous conditions. C₃A phase dissolves immediately after the first contact of cement with water and its dissolution is stopped when the minimal heat flow in the induction period is reached. During hydration reaction of alite, the dissolution of C₃A phase is retarded. The re-dissolution of C₃A phase occurs after the all present sulfates are consumed. This process causes the rapid AFt precipitation [2].

The required sulfates for rapid AFt precipitation are released to the solution from the C-S-H gel after sulfate depletion [3]. The source of C₃A necessary for AFt formation during the time between induction period and the sulfate consumption are amorphous hydroaluminates. These hydroaluminates are formed from C₃A phase in the beginning of the overall hydration reaction [4]. The retardation of C₃A phase should be caused by sorption of sulfate ions to its surface. The peak position assigned to sulfate depletion is dependent on the sulfate content in the cement [5]. The occurred retardation also influences the strength of hardened paste [6]. The cement particle size strongly affects the velocity of the sulfate depletion. The fine particles cause rapid sulfate consumption which can be seen on the calorimetry curve as a strong sharp peak. While, the coarse particles need more time for consumption reaction and can be seen as a weak broad peak. Nevertheless the hydration heat of both processes is identical [7]. Some cement admixtures can be considered as a source of reactive aluminates. For example, the high furnace slag (as a typical cement admixture) is not involved to the aluminate reaction but influences the reaction by filler effect [8].

2. Materials and methods

Portland cement was prepared by ball milling of Portland clinker (Českomoravský cement a.s., plant Mokrá, CZ) with resulted specific surface area 400 m²/kg (determined via Blaine method). Gypsum (commercially purchased; phase composition – 73.6 wt. % of gypsum and 26.4 wt. % of bassanite; Penta, CZ) was used as setting regulator. Alfabond 300 (commercially purchased; phase composition - boehmite and ρ -alumina; Almatix, factory Leetsdale, USA) was used as substitute of clinker and gypsum species. Samples for calorimetry measurements were mixed and homogenized in vibrational mill in stainless steel bowl for 10 s. Samples for mechanical properties determination were ball milled for 10 min. The clinker composition is summarized in Table 1. The composition of the measured samples is shown in Table 2. The particle size of the samples was assessed by laser diffractometry (Helos KR, Sympatec) and is shown on Fig. 1a.

Table 1. Chemical and phase composition of the clinker.

Chemical composition	(%)	Phase composition	(%)
CaO	70.6	C ₃ S	76.6
SiO ₂	19.2	C ₂ S	8.5
Al ₂ O ₃	3.9	C ₃ A	3.0
Fe ₂ O ₃	5.1	C ₄ AF	11.9

Table 2. Composition of measured samples.

Sample	Clinker (%)	Gypsum (%)	AB300 (%)	Sample	Clinker (%)	Gypsum (%)	AB300 (%)
1.a	95.25	4.75	0	2.c	94.00	6.00	0.50
1.b	95.00	5.00	0	2.d	94.00	6.00	0.75
1.c	94.75	5.25	0	2.e	94.00	6.00	1.00
1.d	94.50	5.50	0	3.a	92.50	7.50	1.00
1.e	94.25	5.75	0	3.b	90.50	9.50	2.00
1.f	94.00	6.00	0	3.c	93.25	6.75	1.50
2.a	94.00	6.00	0.10	3.d	92.50	7.50	2.00
2.b	94.00	6.00	0.25				

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