Heating Rate and Liquid Glass Content Influence on Cement Brick Dehydration

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Abstract. Peculiarities of Portland cement dehydration in different hydrate phases with sodium water glass have been given. Three endoeffects were determined during non-isothermal heating, connected with ettringite dehydration and water extraction at temperature ranges 98.7–110.0 °C, calcium hydroxide decomposition at temperature ranges 439.4–450.7 °C and secondary carbonates decomposition at temperature ranges 657.4–669.3 °C. We experimentally proved that the rates of dehydration of hydrated Portland cement was significantly influenced by the liquid glass concentration. Optimum liquid glass content was grounded in the protective layer of composite finishing material, modified with low-temperature plasma.

Keywords: Plasma-chemical modification · Dehydration · Cement brick · Soda water glass

1 Introduction

Plasma-chemical modification is one of the promising technologies of creating protective–decorative coatings in the manufacture of finishing construction materials for building and construction faces (Bondarenko et al. 2018a, b; Bessmertny et al. 2018; Bondarenko et al. 2016; Volokitin et al. 2016). Dehydration, melt formation and accumulation during plasma melting take second fractions, and the surface is heated up to 2000 °C. As a result of high temperature impact hydro silicate dehydration in the surface layers can result in micro cracking and protective-decorative coating softening, as well as coating adhesion strength reduction and lowering of cold resisting properties.

Insufficient technology elaboration on reducing heat impact consequences and dehydration minimizing plasma melting of cement concrete does not allow wide application of these materials on the national market. That is why the main task in developing treatment technologies for materials based on cement matrix is composition development for protective coating which eliminate these processes.

2 Methods and Approaches

To prove the efficiency of Portland cement and liquid glass application in the protective coating during manufacture of composite finishing material with plasma surface treatment the samples were prepared at water/concrete ratio 0.3 from pure Portland cement (CEM I 42,5 H) and with 5 and 10% of soda water glass ($\rho = 1,4 \text{ g/sm}^3$, silica modulus 2.8) of water of mixing. After hardening at normal conditions during 28 days, the samples were exposed to differential-thermal analysis.

Plasma-chemical surface modification is done in non-isothermal conditions at heating rate $3000 \text{ }^\circ\text{C/min}$. It makes impossible to study dehydration in real conditions of plasma heating. This process was simulated with simultaneous thermal analysis device Netzsch STA 449 F3 Jupiter at heating rates $5 \text{ }^\circ\text{C/min}$ and $10 \text{ }^\circ\text{C/min}$ with maximum heating rate $1000 \text{ }^\circ\text{C}$.

3 Results and Discussion

The thermograph of pure hydrated Portland cement shows three endoeffects (Table 1). The first endoeffects, in the temperature range $98.7\text{--}110.0 \text{ }^\circ\text{C}$ in the low temperature area, is connected with ettringite dehydration ($\text{Ca}_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_{12}\cdot 26\text{H}_2\text{O}$) and water extraction. Endoeffects of these two processes superimpose each other. The second is connected with calcium hydroxide dehydration ($\text{Ca}(\text{OH})_2$) and happens at temperature ranges $439.4\text{--}450.7 \text{ }^\circ\text{C}$. The third endoeffects ($657.4\text{--}669.3 \text{ }^\circ\text{C}$) is connected with the secondary hydro carbonates dehydration (CaCO_3). Complete water extraction is at $900 \text{ }^\circ\text{C}$.

Table 1. Changing of endoeffects with the introduction of liquid glass and heating range 5 and $10 \text{ }^\circ\text{C/min}$

Endoeffect producer	Pure hydrated Portland cement		Portland cement with 5% liquid glass		Portland cement with 10% liquid glass	
	Heating range, °C/min					
	5	10	5	10	5	10
Ettringite and physically-coupled water	98.7	110.0	92.6	106.4	92.8	108.0
Calcium hydroxide	439.4	450.7	437.8	450.6	438.0	452.6
Secondary carbonate and hydro silicate	657.4	669.3	662.0	683.1	663.0	693.6

Similar results were received with the hydrated Portland cement after adding 5 and 10% liquid glass (Table 1).

A positive effect of liquid glass adding on secondary carbonate and hydro silicate endoeffects, which are responsible for cement brick softening and micro cracking at higher temperature range, can be explained by effect of encapsulation of hydrate phases with coating of liquid glass.

Adding sodium silicate solute into Portland cement in the amount 5 and 10% takes down mass loss (TG) in ettringite dehydration area (Fig. 1). But in high temperature area dehydration intensity increases up to 2–3%, it is especially notable with 10% liquid glass.

Fig. 1. Dependence of water loss on time at heating range 10 °C/min: — Portland cement; — Portland cement with 5% liquid glass; — Portland cement with 10% liquid glass

The highest dehydration rate is in low temperature area (Fig. 2), which is caused by ettringite dehydration (first climax). The second and third climaxes are connected with dehydration of calcium hydroxide, secondary carbonate and different hydro silicates, are below the first climax by magnitude.

Fig. 2. Dependence of water loss on time at heating rates 10 °C/min: — Portland cement; — Portland cement with 5% liquid glass; — Portland cement with 10% liquid glass

Dehydration rate decrease during the first and the second climax for cement brick with 5 and 10% of liquid glass has a significant impact on micro cracking minimization in the surface layer of protective–decorative coating of composite finishing material at plasma-chemical modification. Dehydration intensification can result in microcracks increase and reduce to zero the positive influence of liquid glass in the coating. This effect takes place at adding 10% liquid glass into Portland cement. Thus, the received

laws analysis of mass loss and dehydration rate of the studied compositions drew to a conclusion that the optimal is liquid glass component in the ratio 5% of mixing water.

4 Conclusions

The influence pattern character has been determined of liquid glass content on ettringite dehydration rate, calcium hydroxide and secondary carbonate, which is in endoeffects shift in low temperature area to lower temperatures, and in high temperature area to the area of high temperatures. This minimizes dehydration in low temperature area, cement brick softening and micro cracking and as a result provides adhesion strength improvement of protective-decorative coating with the concrete layer.

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