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Effect of fly ash on the kinetics of Portland cement hydration at different curing temperatures

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ABSTRACT

This paper describes the effect of fly ash on the hydration kinetics of cement in low water to binder (w/b) fly ash-cement at different curing temperatures. The modified shrinking-core model was used to quantify the kinetic coefficients of the various hydration processes. The results show that the effect of fly ash on the hydration kinetics of cement depends on fly ash replacement ratios and curing temperatures. It was found that, at 20 °C and 35 °C, the fly ash retards the hydration of cement in the early period and accelerates the hydration of cement in the later period. Higher the fly ash replacement ratios lead to stronger effects. However, at 50 °C, the fly ash retards the hydration of the cement at later ages when it is used at high replacement ratios. This is because the pozzolanic reaction of the large volumes of fly ash is strongly accelerated from early in the aging, impeding the hydration of the cement.

1. Introduction

Fly ash is widely used as a supplementary cementitious material in high performance concrete because of its benefits in enhancing both fresh and long-term concrete properties and as it promotes eco-friendly construction. Investigations have been carried out mainly to elucidate the pozzolanic reaction of fly ash and its effect on the microstructure of the fly ash-cement paste. Escalante et al. [1] reported that, in paste with water to binder (w/b) ratios of 0.50 and cured in water, fly ash enhanced cement hydration at low temperatures slightly but showed a retarding effect at elevated curing temperatures. Although the effect of fly ash on hydration has been established experimentally, the quantitative influence of fly ash on the kinetics of cement hydration is not well understood. In particular, for modern high-performance concretes with low w/b ratios, the effect of the fly ash on the cement hydration may be different [2]. To predict the performance of fly ash concrete accurately throughout its service life, a more quantitative understanding of the effect of fly ash on cement hydration in low w/b ratio cementitious mixtures is needed.

Kinetic modeling based on the shrinking-core theory can be used to quantify the hydration kinetics of cement. For ordinary Portland cement paste, Park [3,4] and Maruyama [5] have demonstrated the use of this model to simulate the hydration of cement in general and of the different cement components. Results showed good agreement between the model simulations and the experimental data. However, only little experimental data were provided for the verification. Recently, Wang et al. [6–9] has described the application of this model in predicting hydration of fly ash blended cement. Cement hydration and the pozzolanic reaction of fly ash were simulated simultaneously by considering the interaction between the production of calcium hydroxide by cement hydration and its consumption by the pozzolanic reaction of fly ash. This work was able to predict hydration related properties such as chemically bound water, paste porosity, and internal temperature rises, however the development of the degree of hydration of the fly ash containing cement has not been fully elucidated. Only measured hydration data for Portland cement paste obtained from [10] was presented as verification of the model. Termkhajornkit [11] and Saengsoy [12] have pointed out that the degree of hydration of the cement in fly ash-cement paste was higher than that in pure Portland cement paste. This suggests that to simulate the hydration kinetics of the cement in fly ash-cement blends using this model, hydration data for the cement in pure Portland cement paste is not suitable for model calibration. Hydration data for this kind of hydration must be obtained specifically from the blended fly ash-cement paste.

The XRD-Rietveld analysis can be used to monitor cement hydration, but in the case of cement containing fly ash, a part of the cement is replaced by fly ash, and thus the relative amounts of individual cement components are lower. This could increase the relative errors of the XRD-Rietveld analysis of the low-content components such as C_3A, and C_4AF [13]. Although there are some studies reported the interactions among the hydration of individual cement components [14,15], these interactions have not been quantitatively established and the mechanisms of these interactions are not well understood. The research to be reported here will first

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