Simulation of Hydration of Portland Cement Blended With Mineral Admixtures

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ABSTRACT

Supplementary cementing materials (SCM), such as silica fume, slag, and low-calcium fly ash, have been widely used as mineral admixtures in high strength and high performance concrete. Due to the chemical and physical effect of SCM on hydration, compared with Portland cement, hydration process of cement incorporating SCM is much more complex. This paper presents a numerical hydration model which is based on multi-component concept and can simulate hydration of cement incorporating SCM. The proposed model starts with mixture proportion of concrete and considers both chemical and physical effect of SCM on hydration. Using this proposed model, this paper predicts the following properties of hydrating cement-SCM blends as a function of hydration time: reaction ratio of SCM, calcium hydroxide content, heat evolution, porosity, chemically bound water and the development of the compressive strength of concrete. The prediction results agree well with experiment results.

1. introduction

The Supplementary cementing materials (SCM), such as silica fume, slag, and low-calcium fly ash, are by-products from metallurgical industries and thermal power plants. They have been widely used as mineral admixtures in high strength and high performance concrete.Using this proposed model, this paper predicts the properties of hydrating cement-SCM blends as function of hydration time. The prediction results agree well with experiment results.

2. Hydration Model of Ordinary Portland Cement

On the basis of Park' s model [1-2], some improvements are done to consider cement particle size distribution and cement mineral component. The basic hydration equation of each mineral composition in cement particles can be described as following equation (1):

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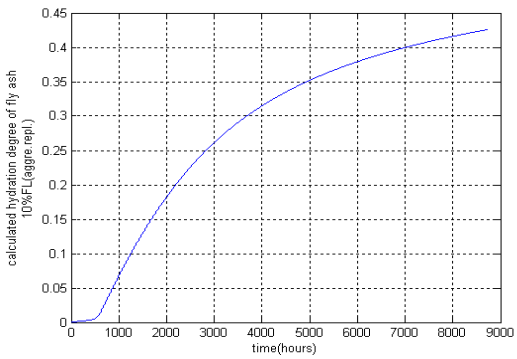
$$\frac{d\alpha_i^j}{dt} = \frac{3C_{w\infty}}{(v_i + w_{ag})r_0^j \rho_i} * \frac{1}{(\frac{1}{k_d} - \frac{r_0^j}{D_{ei}}) + \frac{r_0^j}{D_{ei}}(1-\alpha_i^j)^{\frac{-1}{3}} + \frac{1}{k_{ri}}(1-\alpha_i^j)^{\frac{-2}{3}}} \quad (1)$$

3. Hydration Model for Cement-SCM Blends

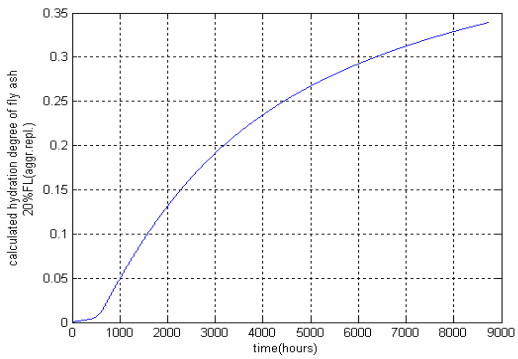
Due to higher particle size, hydration rate of low-calcium fly ash is much lower than silica fume. In simulation it is assumed that pozzolanic reaction in cement-FL blends includes dormant period, reaction process and diffusion process, which is shown as following:

$$\frac{d\alpha_{reacted}}{dt} = \frac{m_{CH}}{P} \frac{3}{v_{FL} r_{FL0} \rho_{FL}} * \frac{1}{(\frac{1}{k_{dFL}} - \frac{r_{FL0}}{D_{eFL}}) + \frac{r_{FL0}}{D_{eFL}}(1-\alpha_{reacted})^{\frac{-1}{3}} + \frac{1}{k_{rFL}}(1-\alpha_{reacted})^{\frac{-2}{3}}} \quad (2)$$

the predicted reaction degree of fly ash is shown in figure 1.



(1-a) reacted ratio of 10%FLA



(1-b) reacted ratio of 20%FLA

Figure 1 the calculated reacted ratio of total fly ash versus time

4. Conclusion

In this paper, based on multi-component concept, a numerical hydration model which can simulate hydration of cement-SCM blends is built. The proposed model considers both Portland cement hydration and pozzolanic activity. Using this proposed model, this paper predicts the properties of hydrating cement-SCM blends as function of hydration time.

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references

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