

# 論文の要旨

題 目 Effects of Internal Alkali Activation on Chemical and Mechanical Properties of Fly Ash Cement Systems  
( フライアッシュ・セメント系の化学的・力学的特性に及ぼす内部アルカリ活性化の影響 )

氏 名 Bui Phuong Trinh

Fly ash concrete has been used widely in the construction because of taking the advantages of the improved durability, effective cost, and environmental protection. However, low-calcium fly ash concrete has the lower strength than the cement concrete due to slow pozzolanic reaction of fly ash. This results in its limitation for the production of high strength concrete. In the recent years, several studies have suggested alkali activations to accelerate the pozzolanic reaction of fly ash particles. One of alkali activations is performed by mixing one or some types of alkaline solutions with fly ash directly and curing at high temperature, which could limit to apply in the practical use. The curing condition at normal temperature in alkali activation needs to be considered as the more practical method. In addition to the alkali activation, internal curing has been investigated for improving the properties of high strength concrete with a low water to binder ratio. Nevertheless, the previous studies of internal curing have discussed only the effects of internal water supplied from internal curing agents (such as pre-wetted lightweight aggregate, super absorbent polymers, porous ceramic waste aggregate (PCWA), and so on) on some properties of concrete. The internal acceleration for pozzolanic reaction by using PCWA imbibing an alkali solution, however, has not been investigated in the fly ash concrete yet. Based on this background, the aim of this study is to investigate an internal alkali activation (IAA) on the fly ash cement systems cured at normal temperature so that the fly ash concrete using PCWA imbibing alkali solution could get the maximized strength and enhanced durability.

To achieve the above-mentioned purpose, this thesis is organized as follow:

Chapter 1 describes the background, aims, and methodology of this study.

Chapter 2 provides a brief literature review about the effects of fly ash, the mechanisms and effects of internal curing, and the alkali activation on the chemical reaction and the long-term mechanical properties of the fly ash cement systems.

Chapter 3 presents the experimental program consisting of materials and mixture proportions, the fundamental models as IAA, the mixing and casting progress, the curing condition for the fly ash cement system. The experiments of fundamental models were performed to study the effects of IAA on the chemical and mechanical properties of the fly ash cement systems. They were (1) an original model through an installed syringe, (2) a model of internal activation by using PCWA. In addition, the effects of IAA on the mechanical properties of fly ash concrete using PCWA prepared in saturated-surface dry condition after the immersion in alkali solution for 7 days were investigated. Three types of IAA used in this study were (1) 0.1mol/L NaOH solution (pH = 13.0), (2) saturated Ca(OH)<sub>2</sub> solution (pH = 12.6), and (3) water for a reference. In addition to the effects of types of IAA, the effects of starting time of IAA on the pozzolanic reaction of fly ash cement systems were also studied. Cement systems with 0%, 20% and 40 mass% of fly ash replacement ratios were used, while the

concrete using PCWA by 0% and 40 vol.% of coarse aggregate replacement ratios were used in this study. In order to evaluate the effects of IAA, the measurements of  $\text{Ca(OH)}_2$  (CH) content and porosity, the calculation of CH consumption by the pozzolanic reaction, and test of the compressive strength of concrete were carried out by thermal gravimetric analysis, mercury intrusion porosimetry, and strength test, respectively. In addition, a confirmation by SEM examination was performed on this study.

Chapter 4 discusses the effects of types and starting time of IAA on the chemical reaction of the fly ash cement systems by examining the CH content and consumption of CH. The experiments demonstrate that IAA not only decreased the CH content but also increased the CH consumption by the pozzolanic reaction in the cement paste with 40% replacement of fly ash (FA40). Moreover, an injection of saturated  $\text{Ca(OH)}_2$  solution reduced the CH content and increased the consumption of CH in FA40 more than that of water or NaOH solution. In addition to the effects of types of IAA, it can be found that IAA from 3 months after casting increased the consumption of CH by pozzolanic reaction in FA40 more than that from 1 month after casting. Briefly, IAA was effective in accelerating the pozzolanic reaction and promoting the cement hydration of the fly ash cement systems. This was also confirmed by SEM examination.

Chapter 5 discusses the effects of IAA on the mechanical properties of the fly ash cement systems by measuring the porosity and hardness, and testing the compressive strength of the fly ash concrete. It shows that IAA decreased the total pore volume in FA40. Furthermore, pore size distribution was altered by IAA, with the decrease in the volume ratio of 20-330 nm pores to the total pore and the increase in that of 3-20 nm pores in FA40. It indicates that IAA was effective in accelerating the pozzolanic reaction of the fly ash cement systems. According to the decrease in the volume ratio of 20-330 nm pores to the total pore and the increase in that of 3-20 nm pores, it can be said that the IAA from 3 months after casting was more effective in accelerating the pozzolanic reaction of the fly ash cement paste at the age of 12 months than that from 1 month after casting. The experiment by using the model of internal activation with PCWA indicates that IAA also improved the microstructure of interfacial transition zone (ITZ) and bulk paste in the fly ash cement systems at the age of 6 months. In addition, the effects of IAA by using PCWA on the mechanical properties of the fly ash concrete can be briefly concluded that although the short- and long-term compressive strengths in the fly ash concrete using 40% replacement of PCWA imbibing the alkali absorption were nearly the same as those without PCWA, the macropore volume (pores ranging 0.05 – 50  $\mu\text{m}$ ) was reduced in the presence of IAA at the ages of 28, 182, and 364 days. Moreover, pore size distribution was altered by IAA, with the decrease in the volume ratio of 20-330 nm pores to the total pore and the increase in that of 3-20 nm pores. Briefly, the pozzolanic reaction of the fly ash cement systems was accelerated by IAA, with the decrease in the volume ratio of 20-330 nm pores to the total pore, the increase in the volume ratio of 3-20 nm pores, and the improved ITZ microstructure although the enhanced compressive strength was not shown.

Chapter 6 proposes the mechanisms of IAA accelerating the pozzolanic reaction as well as promoting the cement hydration of the fly ash cement system. In addition, the differences in the starting time of IAA mechanism affecting the microstructure development in FA40 and the differences of each type of IAA in the activation mechanism of the fly ash particles are also described.

Chapter 7 states the conclusions of this study. Recommendations for future work are also provided.