Corrosion mechanisms of steel reinforcement in fly ash/slag based powder form of geopolymer concrete

by TRAN HUYEN VU

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under the supervision of Dr Nadarajah Gowripalan, Professor Vute Sirivivatnanon and Associate Professor Pre De Silva

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, *Tran Huyen Vu,* declare that this thesis, is submitted in fulfilment of the requirements for the award of *Doctor of Philosophy*, in the *School of Civil and Environmental Engineering/Faculty of Engineering & Information Technology* at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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ABSTRACT

Investigation of the durability related aspects of geopolymer concrete has been increasingly conducted worldwide. The suitability of geopolymer concretes in structural applications, still, has not been well proven because of the lack of information on service history and durability performance. Further, the conventional production techniques of geopolymer binders requiring the handling of highly alkaline liquids that are dangerous. Therefore, one-part geopolymer, a new way of producing geopolymer, is introduced to deal with such a safety issue. However, one-part geopolymer invariably has an issue related to a short setting time. To promote the use of geopolymer materials in structure applications, this study aimed to investigate on carbonation and chloride resistance of one-part fly ash/slag geopolymer concretes, which have been deemed as the durability issues attributed to corrosion of steel reinforcement in geopolymer materials. Additionally, the possibility of using a sodium-based set retarder to address the issue of short setting time was included in the investigation.

The investigation of carbonation focused on changes of carbonation depth and pH under both accelerated and natural carbonation conditions. The influence of carbonation on porosity and pore size characteristics of one-part fly ash/slag geopolymer mortar was also investigated by using neutron tomography and mercury intrusion porosimetry (MIP). For assessing chloride resistance, accelerated chloride diffusion, rapid chloride permeability test (RCPT), and the movements of ions in RCPT were performed. A brief examination of chloride diffusion at seawater concentration was also carried out. To explore how the set retarder affects the setting time and other early age properties of one-part geopolymer concrete, changes of setting time, heat released, and compressive strength when different amounts of retarder

applied were thoroughly examined. Scanning electron microscopy (SEM) with energy dispersive X-ray spectrometry (EDS) was also performed in order to supplement the findings of the other tests.

The key findings indicated that using the set retarder mentioned above prolonged the setting time of one-part geopolymer binders and reduced the heat released by activation reactions. The compressive strength, however, was decreased when increasing the percentage of retarder. This problem could be avoided by using the retarder with an amount of 2-6%. The results obtained also showed that carbonation alone might not lead to steel corrosion in one-part geopolymer concrete investigated because the pH in carbonated parts was always higher than 10. For assessing chloride resistance of one-part fly ash/slag geopolymer concretes in an accelerated test in 16.5% NaCl solution, 40% fly ash/ 60% slag geopolymer concrete had a lower chloride resistance than OPC concretes, while chloride resistance of 60% fly ash/ 40% slag geopolymer concrete was worse. Due to the presence of both fly ash and slag in the precursor, chloride ions were physically and chemically bound when penetrating in the one-part geopolymer concretes. Regarding RCPT, using 60 voltage, advocated in ASTM C1202, caused the issue of overheating. RCPT performed at 30 voltage was highly suggested because it was well correlated with the accelerated chloride diffusion test. However, it was difficult to distinguish the ability of chloride resistance between different one-part geopolymer concretes based on the charge passed obtained in RCPT. It was because the charge passed was contributed by the movement of all ions present, not by only Cl^-.

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