論 文 の 要 旨

題 目 EFFECTS OF CHLORIDE ION ON MECHANICAL PROPERTIES AND DURABILITY OF SEA SAND CONCRETE CONTAINING SUPPLEMENTARY CEMENTITIOUS MATERIALS UNDER ACCELERATED CARBONATION
(セメント質混和材を含む海砂使用コンクリートの促進炭酸化時における力学特性及び耐久性に及ぼす塩化物イオンの影響)

氏 名 DANG QUOC VIET

The demand for river sand as a common fine aggregate for concrete production has significantly increased, resulting in overexploitation and significant environmental impacts. In this circumstance, non-desalted sea sand (NSS) can be considered as an alternative material when river sand is unavailable in the coastal areas. Generally, there is a high concentration of chloride ion in NSS, which can affect the mechanical properties and durability of concrete. Supplementary cementitious materials (SCMs) such as fly ash (FA) or ground granulated blast furnace slag (BFS) has been widely used in concrete production as a partial replacement of ordinary Portland cement (OPC) to improve the mechanical properties and durability of concrete as well as bind chloride ion in NSS. However, concrete containing FA or BFS was very sensitive to carbonation. Carbonation is a process in which atmospheric carbon dioxide penetrates the cementitious materials and reacts with the hydration products, resulting in the change in the microstructure of concrete. Although carbonation is one of the most common factors affecting mechanical properties and durability performance of concrete in service life, most researchers have evaluated the feasibility of NSS for concrete production without considering the effects of carbonation. To extensively verify the applicability of NSS for concrete production, the simultaneous effects of internal chloride ion from NSS and carbonation on the mechanical properties and durability of concrete containing SCMs were investigated up to the age of 182 days in this study. Additionally, the effect of the chloride ion and SCMs replacement on the variation of fresh concrete properties was studied.

This dissertation is organized into seven chapters as follows:

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

Chapter 2 presents a brief literature review on the investigation of the applicability of NSS for concrete production. The effects of FA or BFS as well as carbonation on the mechanical properties and durability of concrete are also expressed.

Chapter 3 illustrates the experimental program of this study, including the materials and mixture proportions, the mixing and casting progress, the curing conditions and the measurements. All the concrete specimens were designed with a constant water to cementitious materials of 0.50. Fly ash and BFS were used to partially replace OPC with the ratios of 15% and 45% by mass, respectively. Fine aggregates included NSS and desalted sea sand (DSS). After mixing, the fresh concrete was divided into two parts. One part was used to determine the fresh concrete properties. The other was used to measure the properties of hardened concrete. After casting, the surface of all the specimens was sealed with aluminum adhesive and cured under sealed condition at the constant temperature of 20 ± 2 °C for 28 days. A half of concrete specimens at the age of 28 days were completely demolded and exposed to accelerated carbonation chamber with 5% concentration of CO_2, at 60% relative humidity, and 20 ºC until 182 days to investigate the effects of carbonation on mechanical properties and durability of concrete. Meanwhile, the rest of concrete specimens was continuously sealed and placed at 20 ± 2 °C. The mechanical properties of concrete including compressive strength and modulus of elasticity were measured at the designated ages up to the age of 182 days. The thermal gravimetric analysis, mercury intrusion porosimetry, ion chromatography analysis, and scanning electron microscopy were carried out to determine the physical-chemical and microstructure properties of concrete under sealed and carbonation conditions. The effect of chloride ion as well as carbonation on the permeability, sorptivity, and carbonation depth were also determined. On the other hand, the effect of carbonation on the chloride binding capacity of concrete was also carried out in this study.

Chapter 4 demonstrates the effect of chloride ion in NSS on the properties of fresh and hardened concrete containing FA and BFS. The obtained results showed that the chloride ion in NSS had no influence on the slump loss and air content reduction of concrete for 60 min after mixing. Chloride ion in NSS not only accelerated cement hydration but also enhanced pozzolanic reactivity of FA and hydraulicity of BFS at early ages (i.e., 3 and 7 days), resulting in significant increase in the compressive strength and elastic modulus of concrete. The mechanical properties of FA and BFS concretes combining with the presence of chloride ion in NSS were improved after 91 days in comparison with the reference concrete under sealed condition. Moreover, the presence of chloride ion in NSS also contributed to the improvement the permeability and sorptivity of concrete. Briefly, the expected results contribute to the useful knowledge and discussion for verifying the applicability of NSS for concrete production.

Chapter 5 evaluates the mechanical properties of NSS concrete exposed to accelerated carbonation. The effect of chloride ion and carbonation on the portlandite and calcium silicate hydrated contents was investigated through thermal gravimetric analysis. It should be emphasized that the NSS concretes showed better mechanical properties than DSS concretes even under carbonation condition until 182 days regardless of SCMs replacement. The carbonation process might cause the remarkable formation of cracks for FA or BFS concrete in comparison with OPC concrete. As a result, the modulus of elasticity of FA and BFS concretes was decreased under carbonation condition. However, the decrease in modulus of elasticity of concrete under carbonation could be restricted by the presence of chloride ion in NSS. Based on these results, it concludes that the NSS can be potential materials as fine aggregate for concrete production even when concerning the influence of carbonation.

Chapter 6 presents the effect of chloride ion in NSS on the carbonation resistance and sorptivity coefficient of concrete containing SCMs under accelerated carbonation. All the experimental results showed that chloride ion in NSS could improve the carbonation resistance of concrete compared with concrete without chloride ion regardless of SCMs replacement. The cracks significantly generated in SCMs concretes due to carbonation led to the significant increase in the sorptivity coefficient of concrete under carbonation condition in comparison with that under sealed condition. However, the presence of chloride ion in NSS could restrict the increase in the sorptivity coefficient of concrete under carbonation condition. Although the chloride binding capacity of concrete could increase when concrete incorporated with FA and BFS, the carbonation significantly decreased the chloride binding performance of concrete, especially concrete containing FA and BFS.

Chapter 7 expresses the conclusions of this study. The recommendations for future works are also proposed. It should be emphasized that NSS concretes did not perform worse in mechanical properties and durability than DSS concretes even considering the carbonation. Therefore, it concludes that NSS can be considered as an alternative fine aggregate for production of plain concrete at coastal areas.