論 文 の 要 旨

題目 Effects of Shirasu Natural Pozzolan and Limestone Powder on the Strength Development and Chemical Resistance of Concrete

（しらすならびに石灰石微粉末がコンクリートの圧縮強度および化学抵抗性に及ぼす影響）

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Concrete is the most widely used construction material and concrete structures have been faced with a variety of aggressive environment. Recently, seawater in coastal acid sulfate soils contains many aggressive chemical compositions for concretes structure and affects huge areas in the world. In addition, the environment in some sewer systems can become very aggressive, especially in the case of sulfuric acid formed by the bacterial action or industrial products combined with magnesium chloride which is used as deicing salt in cold climate areas and drains into the sewer system. In these environments, H^+, SO_4^{2-}, Mg^{2+}, Cl^- ions are considered as the most destructive ions for concrete structures. However, very limited studies have examined the detrimental effect of these ions on the durability of concrete which associated with the service life and maintenance cost of civil infrastructure. The present study aims at investigating the effect of Shirasu, a large deposit of pyroclastic flows in Kyushu island of Japan, and limestone powder as fine aggregate in concrete with respect to compressive strength improvement and the chemical resistance of concrete against aggressive environments containing H^+, SO_4^{2-}, Mg^{2+}, Cl^- ions.

To achieve the above-mentioned purposes, this thesis is divided into of sixes chapters, and detailed organization of the thesis is described as follows:

Chapter 1 presents the background, purposes, and methodology of this study.

Chapter 2 provides a brief literature review on strength development and durability of concrete by considering the effects of limestone powder and Shirasu natural pozzolan.

Chapter 3 presents the experimental program consisting of materials, the mixing, and the casting procedure. In this study, Shirasu and limestone powder were used as a partial fine aggregate replacement. The replacement ratios of fine aggregate by limestone powder and Shirasu were 5% and 55% by volume, respectively, based on referring to some previous studies. After casting, specimens of each concrete mixture, including cylindrical ones with 100 mm diameters and 200 mm heights and cubic ones with dimensions of 100 × 100 × 100 mm, were separated into two groups: one was stored under normal curing temperature condition in which specimens were cured in a sealed condition with aluminum tape at 20°C until the designated test ages (i.e., 3, 28, and 91 days for the compressive strength test); whereas other was placed under sealed

condition with aluminum tape at high curing temperature history of 60°C for 8 hours followed by cooling process in the curing chamber. For the immersion test, specimens cured until the age of 56 days were immersed in a mixed solution containing 3% H_2SO_4 and 5% $MgCl_2$. The effects of limestone powder and Shirasu on properties of concrete cured at different initial temperatures were evaluated via the measurement of compressive strength, $Ca(OH)_2$ content by using thermogravimetric analysis, X-ray diffraction analysis, erosion depth, chloride penetration depth, the mass loss and compressive strength reduction after immersion in the mixed solution.

Chapter 4 discusses the effects of limestone powder and Shirasu natural pozzolan on the strength development and chemical resistance of concretes cured in normal curing temperature with sealed aluminum adhesive tape through microstructural and chemical investigations. The results showed that the use of Shirasu natural pozzolan as a fine aggregate replacement can improve the strength development of concretes after 28 days curing. In addition, after 22 weeks of immersion in the mixed solution, the compressive strength loss, neutralization depth and chloride penetration depth of concretes containing Shirasu were lower than those of concretes without Shirasu. It indicated that the replacement of fine aggregate with Shirasu can improve not only the compressive strength but also the chemical resistance of concrete to the aggressive environment. In contrast, the role of limestone powder in the improvement of compressive strength was insignificant. In addition, after immersion in the mixed solution, highest compressive strength loss, neutralization depth, erosion depth of concretes containing limestone powder was attributed to the higher contents of portlandite and calcite which were vulnerable to the aggressive chemical reaction.

Chapter 5 discusses the effects of different initial curing temperatures on the strength development and chemical resistance of concrete to the mixed solution through microstructural and chemical investigations. The results demonstrated that initial high curing temperature increased the compressive strength of concrete after aging for 3 days but reduced it at later ages (i.e. 28 and 91 days) in comparison with that of concrete cured at normal temperature of 20°C. In addition, initial high curing temperature can accelerate the pozzolanic reactivity of Shirasu, leading to an increase in the compressive strength of concretes containing Shirasu. Furthermore, the deterioration of concretes cured at high temperature by the attack of the mixed solution was less severe than that of concretes cured at normal temperature.

Chapter 6 states the conclusions of this research. Recommendations for future work are also provided.