第５号様式

論文審査の要旨

博士の専攻分野の名称	博　士　（　工学　）	氏名	Saludung Apriany
学位授与の要件	学位規則第４条第1・２項該当		

論　文　題　目

Studies on Engineering Properties Improvement of Geopolymer and Alkali-Activated Slag

（ジオポリマー，アルカリ活性スラグの工学的特性改善に関する研究）

論文審査担当者

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〔論文審査の要旨〕

Alkali-activated materials (AAMs) and geopolymers have appeared as alternative materials that can fully replace ordinary portland cement (OPC) in concrete production. Although AAMs and geopolymers possess mechanical strengths and durability comparable to OPC, their extensive application in the construction field is limited by several factors, including their brittle property and high tendency to efflorescence formation and alkali leaching. The variation of starting materials has also led to the complex investigation of the engineering properties and durability of AAMs. Based on these backgrounds, this research aims to investigate the heat resistance of fly ash-based geopolymer containing ground granulated blast- furnace slag (GGBS), the efflorescence formation and alkali leaching behavior of alkali- activated slag (AAS), and the alkali leaching behavior and mechanical performances of geopolymer reinforced by epoxy resin.

The dissertation includes seven chapters and the detailed organization is described as follows.

Chapter 1 provides the background, objectives, and scopes of this study.

Chapter 2 provides a brief overview of some crucial aspects of the traditional cement industry, AAMs, and geopolymer technology by reviewing some published literature. A brief historical development, basic theory, characteristics, durability, and the importance of AAMs and geopolymers are discussed.

Chapter 3 describes the methodology of this research, including materials (precursors, alkali solutions, and epoxy resin) used, mixture proportions, synthesis procedures, curing conditions, characterizations, and measurement methods. The study on heat resistance utilized low-calcium fly ash and GGBS to produce fly ash-based geopolymer pastes with 0, 15, 30, 45, and 60% replacement of GGBS. The effect of alkali metal type on the heat resistance of geopolymer paste (containing only 45% GGBS) was also investigated by using two combinations of alkali solution: NaOH solution and water glass, and KOH solution and water glass. Small amounts of silica fume

(SF) (0 to 15%) were used to replace GGBS in the production of AAS to investigate the effect of SF on efflorescence formation on AAS. Geopolymer composites were also prepared by incorporating epoxy resin (1% and 2.5% by binder mass) into the geopolymer system. Some characteristics, including alkali leaching behavior, thermal analysis, phase composition, mechanical strengths, microstructure, and porosity of epoxy resin- reinforced geopolymer were investigated.
Chapter 4 presents the investigation results on the properties of geopolymer at high temperatures. The inclusion of GGBS significantly increased the initial compressive strength, but once exposed to elevated temperature, severe damage was observed in geopolymer containing a high amount of GGBS. The damages that occur in high-Ca geopolymer could be attributed to the dehydration of aluminate-substituted calcium silicate hydrate. Using KOH solution and water glass improved the fire resistance of geopolymer, as the specimen exhibited densification of pores and a slight increase of compressive strength after exposure to 950 ℃, while geopolymer using NaOH solution and water glass exhibited a highly porous microstructure. Geopolymer materials performed better heat resistance in terms of phase stability and retained compressive strength than OPC paste.
Chapter 5 discusses the effect of SF on the efflorescence formation and alkali leaching behavior of AAS paste. The inclusion of SF reduced the alkali leaching rate, resulting in lower efflorescence formation. Since efflorescence formation is strongly related to free alkali, the reduction in efflorescence formation could be because the additional silica from SF reduces the Na/Si ratio in the AAS system; thus, less sodium remains unreacted in the matrix. In addition, the inclusion of SF generated micropores. Although previous studies suggested that porosity has a strong correlation to alkali loss, this study did not find such a correlation. In this study, specimens without SF present lower porosity but faster alkali leaching, and rapid efflorescence formation compared to specimens containing SF.
Chapter 6 provides the experimental results of the alkali leaching and mechanical performances of fly ash/GGBS-based geopolymer reinforced by bisphenol F type epoxy resin. The addition of epoxy resin up to 2.5% reduced the alkali leaching rate and total alkali leaching of ambient-cured geopolymer. The compressive and flexural strengths were up to maximum value while doping 1% epoxy resin. Despite reducing the alkali leaching, the inclusion of 2.5% epoxy resin reduced the homogeneity of the matrix. Although geopolymers cured in water leached significant amounts of alkalis, their compressive strength was higher than that of ambient-cured geopolymers, proving that alkali leaching did not negatively influence the compressive strength.
Chapter 7 states the conclusions of this study and some recommendations for future research related to this study.
The examining committee evaluated that the dissertation met the standard of excellence expected of a doctoral candidate at Hiroshima University.

備考：審査の要旨は，1,500 字以内とする。