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Abstract

Influence of Precursor Materials on the Mechanical Behavior of Ambient-Cured One-Part Engineered Geopolymer Composites †

Wee Teo [1,*], Kazutaka Shirai [2] and Jee Hock Lim [3]

[1] School of Energy, Geoscience, Infrastructure and Society (EGIS), Heriot-Watt University Malaysia, Putrajaya 62200, Malaysia
[2] Faculty of Engineering, Hokkaido University, Sapporo 060-8628, Japan; shirai.kazutaka@eng.hokudai.ac.jp
[3] Department of Civil Engineering, Universiti Tunku Abdul Rahman, Bandar Sungai Long, Cheras, Kajang 43000, Malaysia; limjh@utar.edu.my
* Correspondence: t.wee@hw.ac.uk; Tel.: +60-127560230
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Geopolymers are emerging low-carbon cement-free binders that offer a sustainable and environmentally friendly alternative to ordinary Portland cement (OPC). Despite their outstanding environmental friendliness, geopolymers still exhibit inherently brittle behavior similar to that of conventional cement-based concrete. Recently, there has been renewed interest in developing a new material combining geopolymers and Engineered Cementitious Composite (ECC) technologies, called Engineered Geopolymer Composites (EGCs). However, there are two major drawbacks associated with conventional geopolymer binders: firstly, it requires the handling of hostile, corrosive and viscous alkaline solutions; secondly, heat curing is necessary to improve the geopolymerisation process and mechanical properties. To overcome such limitations, a new class of geopolymer composites known as "one-part" or "just add water" geopolymers was developed for this purpose.

The concept of ECCs relies heavily on the micromechanics-based design principles, which provide a guide for tailoring of fiber, matrix and fiber–matrix interfaces to attain desired tensile ductility. Through careful tailoring, the fiber volume fraction usually remains moderate, at typically less than 2.5%. Polyvinyl alcohol (PVA) fiber is the most common type of fiber used in ECCs. To develop a cement-less EGC, a proper consideration of the geopolymer matrix design is essential. Research on EGCs is still relatively new. Preliminary feasibility studies carried out on slag-based EGCs [1] and fly-ash-based EGCs [2] have shown very promising results with a high tensile ductility over 4%. Studies on one-part EGCs conducted by Nematollahi et al. [3] and Alrefaei et al. [4] further assure more detailed investigations are needed for potential applications of this technology in future eco-friendly civil infrastructure.

This paper presents the results of a preliminary investigation on the influence of precursor materials on the mechanical properties of one-part EGCs. The aluminosilicate precursor materials used in this study consisted of a combination of fly ash (FA), ground granulated blast furnace slag (GGBS) and quartz powder (QP). Sodium metasilicate anhydrous was used as the solid alkali activator to synthesize the ambient-cured one-part geopolymer composites. In order to minimize the matrix fracture toughness, all mixtures were prepared without the addition of silica sand. All mixtures were designed with varying proportions of FA, GGBS and QP, amounts of alkali activators and water contents. Mechanical properties were determined by compression and direct tension tests. Fresh properties and microstructure analysis of each mixture were also studied and discussed.

The results indicate that the combination of GGBS with FA improves the reactivity of the mixture and compressive strength and enables a possible ambient curing condition.

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Due to the spherical nature of FA's particle shape, the best ratio for the combination of FA and GGBS in terms of flowability was found to be 70:30. An increase in the number of solid alkali activators used, reduction in the water contents and addition of QP could beneficially increase the compressive strength as well as uniaxial tensile cracking strength, ultimate strength and strain capacity. This was clearly reflected in the microstructure of the geopolymer gel, which showed a more compact and denser morphology.

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