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Mechanical properties, flexural behaviour, and ductility characteristics of fibre-reinforced geopolymer mortar

Adel Kassem Farag Gaddafi [a], U. Johnson Alengaram [a,*], Norazura Muhamad Bunnori [a], S.I. Ibrahim Muhammad [b], Shaliza Ibrahim [c], Mathialagan Sumesh [a]

[a] Centre for Innovative Construction Technology (CICT), Department of Civil Engineering, Faculty of Engineering, Universiti Malaya, 50603 Kuala Lumpur, Malaysia
[b] Water Engineering and Spatial Environmental Governance (WESERGE), Department of Civil Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
[c] Institute of Ocean and Earth Sciences (IOES), University of Malaya, 50603 Kuala Lumpur, Malaysia

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A B S T R A C T

This study aims to explore the potential of ambient-cured geopolymer as a substitute for ordinary Portland cement (OPC)-based mortar. However, due to their brittle nature, geopolymer materials require reinforcement to enhance ductility. To address this, an experimental program was conducted to investigate the effects of adding polypropylene (PP) and micro steel (MS) fibers to fiber-reinforced geopolymer mortar (FRGM) at volume fractions of 0%, 0.5%, 1%, and 1.5%. The ternary blended geopolymer mortar consisting of fly ash (FA), and ground granular blast furnace slag (GGBS), along with a novel pozzolan called eco-processed pozzolan (EPP) was investigated. The present study assessed the hardened properties of the FRGM, including compressive strength, splitting tensile strength, modulus of elasticity (MoE), ultrasonic pulse velocity (UPV), and the compressive strength of the material when exposed to elevated temperatures. The aim of this study was also to investigate the load–deflection response in terms of deflection, load, flexural strength, and toughening mechanisms; and also, the bonding between the fibers and the mortar matrix was examined using field emission scanning electron microscopy (FESEM). The results indicated that including 0.5% PP fibers and up to 1.5% MS fibers marginally improved compressive strength and MoE. The corresponding increments in splitting tensile strengths were 5% and 134%, respectively. The addition of fibers improved the fracture parameters of the FRGM. The inclusion of both MS and PP fibers significantly enhanced post-cracking flexural and toughness energy. At deflection L/150, MS fiber mixes exhibited 4–5 times higher toughness energy than PP fiber mixes, and also its evidently observed in the FESEM micrographs. The incorporation of 1.5% fiber volume to non-fibrous mix resulted in an improvement of 43.2 N.m. and 10.1 N.m. in toughness (T_{150}) for MS and PP mixes, respectively. At an elevated temperature of 600 °C, the FRGM specimens gained a massive reduction in compressive strength, with the maximum result being at 87% for 1.5PP and 71% for 0.5MS. Overall, the MS fiber-reinforced geopolymer mixes exhibited superior performance as compared to PP fibers.

1. Introduction

Concrete is one of the commonly used construction materials and the second most consumed substance on earth after water [1,2]. Cement is used as a binding agent to make concrete, and it accounts for ~10 wt% of concrete; however, it is responsible for ~70% of the greenhouse gas emissions in concrete production [3].

Cement production in the world is around 4.1 billion tons per year. It is expected to continue increase to 6.1 billion tons by 2050 due to the rapid development of infrastructure worldwide [4,5]. However, the production of OPC has a significant negative impact on the environment due to the release of carbon dioxide (CO_2), with 970 kg released into the atmosphere for every ton of OPC manufactured. Global annual carbon emissions from the cement industry account for approximately 5–7% of the world's carbon emissions [6–8].

There have been many research attempts had been taken by the researchers in finding substitute materials for cement such as fly ash (FA), ground granulated blast furnace slag (GGBS), metakaolin (MK), silica

* Corresponding author.
E-mail address: johnson@um.edu.my (U. Johnson Alengaram).

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