Statistical Distributions of the Strength and Fracture Toughness of Recycled Polyethylene-Reinforced Laterite Composites

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Abstract: This paper presents the results of combined experimental and theoretical studies of the statistical distributions of the strength and fracture toughness of recycled polyethylene-reinforced laterite composites for potential applications in building materials. The composites are produced with different volume percentages (0–30% v/v) and particle sizes (~300 ± 0.02, ~600 ± 0.03, ~900 ± 0.03, ~1,200 ± 0.02, ~1,500 ± 0.04, and 1,800 ± 0.03 μm) of powdered polyethylene (PE) in a laterite matrix. The composites with ~900 ± 0.03 μm and 20-volume percentage of PE are shown to have the best combination of flexural-compressive strengths and fracture toughness. The statistical variations in the flexural-compressive strengths and fracture toughness are well characterized by the Weibull distributions. **DOI: 10.1061/(ASCE)MT.1943-5533.0001426.** © *2015 American Society of Civil Engineers.*

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Introduction

The mechanical properties of composites are known to depend on the volume fraction (Lewis and Nielsen 1970) of their constituents, as well as the reinforcement shapes and orientations (Brockenbrough et al. 1991; Gupta and Wang 1993; Masenelli-Varlot et al. 2002). Composites also exhibit statistical variations in their mechanical properties (Van Mier et al. 2002), which are often due to differences in the reinforcement shapes, sizes, and distributions (Brockenbrough et al. 1991; Van Mier et al. 2002). However, most composites contain synthetic fibers and particulate reinforcements, which are often too expensive for widespread applications in most building materials (Jawaid and Abdul Khalil 2011). There is, therefore, a need for lower-cost composites that can strengthen and toughen building materials without inducing excessive variations in their mechanical properties. Within this context, natural fiber-reinforced cement-matrix composites have been developed for applications in sustainable buildings (Savastano et al. 2000). These include cement-matrix composites reinforced with natural fibers such as sisal (Zhong et al. 2007; Tan et al. 2012), eucalyptus fibers (Sapuan et al. 2007), banana-trunk fibers (Tonoli et al. 2010), and bamboo fibers (Okubo et al. 2004; Deshpande et al. 2000).

Ductile phase reinforcements, such as steel fibers (Nataraja et al. 1999; Chen and Chung 1996) and polyethylene (PE) particles (Chen and Chung 1996; Azeko et al. 2015), have also been incorporated into concrete matrices (Chen and Chung 1996; Nataraja et al. 1999) and laterite-concrete matrices (Udoeyo et al. 2006; Azeko et al. 2015) in recent years. Although these have been shown to strengthen and toughen the resulting composites (Udoeyo et al. 2006; Azeko et al. 2015), the steel composites are relatively expensive due to the processing costs associated with the production of steel fibers (Johnston 1974). In contrast, the use of recycled PE reinforcements has been shown to offer a low-cost alternative to the development of robust composite building materials with lower cost than steel-reinforced composites.

As is the case for most engineering composites, the strengths and fracture toughness values of construction composites are expected to exhibit significant statistical variations. These are due to differences in particle size and shape and the variations in defect and crack sizes that are introduced during materials' processing and manufacturing. Such variations have been characterized by Weibull distributions (weak-link statistics) (Alqam et al. 2002; Sakin and Ay 2008), Gaussian (normal) distributions

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