

Strength and fracture toughness of earth-based natural fiber-reinforced composites

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Abstract

This paper presents the results of a combined experimental and theoretical study of the strength, fracture toughness, and resistance-curve behavior of natural fiber-reinforced earth-based composite materials. The composites, which consist of mixtures of laterite, clay, and straw, are stabilized with controlled levels of Ordinary Portland cement. The compositional dependence of compressive, flexural/bend strength, and fracture toughness are explored for different proportions of the constituent materials using composites and crack-tip shielding models. The underlying crack-microstructure interactions associated with resistance-curve behavior were also studied using *in situ/ex situ* optical microscopy. This revealed evidence of crack bridging by the straw fibers. The measured resistance-curve behavior is also shown to be consistent with predictions from small- and large-scale bridging models. The implications of the results are then discussed for potential applications in the design of robust earth-based building materials for sustainable eco-friendly homes.

Keywords

Composites, strength, fracture toughness, crack-tip shielding, crack bridging, resistance-curve behavior

Introduction

Although the choice of building materials is influenced by the cost and availability of robust materials,¹ most developing countries have focused largely on the application of relatively expensive cementitious building materials that have been associated with ~5% of the global carbon dioxide emissions.² This has made it relatively difficult for poor people to afford durable homes in most developing countries. However, in most of these countries, there are large deposits of industrial, agricultural, and human wastes that can be recycled into robust building materials that could make homes more affordable for a significant fraction of the world's rural and urban poor.³

In the case of industrial wastes, such as blast furnace slag, Savastano et al.⁴ have shown that wastes can be mixed with cements to produce robust materials that reduce the amount of cement that is needed to ensure adequate strength and fracture toughness in building materials. Similarly, natural fibers, such as sisal, eucalyptus fiber, bamboo fiber, coconut fiber, and banana fiber have been incorporated into cementitious matrices to produce durable composites that are resistant to crack growth and fracture.⁵ Such composites are now

being used in eco-friendly housing that includes: roofing elements⁶ and building blocks⁷ that reduce the cost of building materials.

Recently, composite building materials have undergone various forms of optimization, with most attention being focused on the introduction of different types of reinforcements. A report reference⁸ suggests that most developed countries have adopted wood fiber-reinforced cement products for buildings. Hence, in

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