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Toughening Behavior in Natural Fiber-reinforced Earth-based Composites

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ABSTRACT

This study presents a combine experimental and analytical investigation of the toughening behavior in natural fiber-reinforced earth-based composites. A specially designed single fiber pullout apparatus was used to provide a quantitative determination of interfacial properties that are relevant to toughening brittle materials through fiber reinforcement. The parameters investigated included a specially designed high strength earth-based matrix comprising of 60% laterite, 20% clay and 20% cement. The toughening behavior of whisker-reinforced earth-based matrix is analyzed in terms of a whisker bridging zone immediately behind the crack tip and interface strength. This approach is consistent with microscopy observations which reveal that intact bridging whiskers exist behind the crack tip as a result of debonding of the whisker-matrix interface. Debonding with constant frictional stress was obtained and this formed the basis for the analytical model considered and the underlying crack-microstructure interactions associated with Resistance-curve behavior was studied using in situ/ex situ optical microscopy to account for the bridging contribution to fracture toughness. The effect of multiple toughening mechanisms (debonding and crack bridging) was elucidated and the implications of the results are considered for potential applications in the design of robust earth-based building materials for sustainable eco-friendly homes.

INTRODUCTION

Recent studies in the area of infrastructural materials have focused largely on development of fiber reinforced composites that provide improved fracture toughness, compared to their matrix materials [1]. The toughening provided by fibers (in fiber-reinforced composites) via crack bridging and other mechanisms, depends significantly on the properties of the matrix, fibers, and the interface(s) between the matrix and fibers [2]. The interfacial shear strength between the matrix and the fibers is often the key to composite toughening and fracture properties [3]. Prior work has also shown that the best overall toughening of ceramic matrix composite may require debonding and frictional sliding to occur at the interfaces between the fibers and matrix [4-5]. Several studies have been carried out to examine the effects of bonding properties between fibers and matrix on the overall toughness of composite materials. These studies focus on interfacial tensile strength, interfacial shear strength or the combined stress state of normal and shear [6-8]. In brittle-matrix composites, the interfacial shear strengths are often characterized by the debond stress or the frictional pull-out stress [9]. The interfacial shear strengths also has strong effects on composite strength and composite fracture toughness [10]. This has motivated several researchers to study the fiber/matrix interface properties in such composites.

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