

Pull-out behavior of natural fiber from earth-based matrix

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Abstract

This paper presents the results of a combined experimental and analytical study of the pull-out behavior of natural fiber (grass straw) from an earth-based matrix. A single fiber pull-out approach was used to measure interfacial properties that are significant to toughening brittle materials via fiber reinforcement. This was used to study the interfacial shear strengths of straw fiber-reinforced earth-based composites with a matrix that consists of 60 vol. % laterite, 20 vol. % clay and 20 vol. % cement. The composites that were used in the pull-out tests included composites reinforced with 0, 5, 10 and 20 vol. % of straw fibers. The toughening behavior of fiber-reinforced earth-based matrix was analyzed in terms of their interfacial shear strengths and bridging zones, immediately behind the crack tip. This approach is consistent with microscopic observations that reveal intact bridging fibers behind the crack tip, as a result of debonding of the fiber–matrix interface. Analytical models were used to study the debonding of fiber from the matrix materials, as well as the toughening due to crack-tip shielding via bridging. The results show that increasing the fiber embedment length and the fiber volume fraction (in the earth/cement matrix) increases the peak pull-out load. The debonding process was also found to be associated with a constant friction stress. The combined effects of multiple toughening mechanisms (debonding and crack bridging) are elucidated along with the implications of the results for the design of earth-based composites for potential applications in robust building materials for sustainable eco-friendly homes.

Keywords

Fiber pull-out, interface, debonding, friction stress, crack bridging, toughening mechanisms

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.^{4–7}

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

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