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Enhanced bamboo composite with protective coating for structural concrete application

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Abstract

Potential application of newly developed bamboo composite material as structural reinforcement called forth for durability test and bond strength examination. Firstly, durability of bamboo composite material and effectiveness of protective epoxy coating were evaluated by subjecting samples to various corrosive environments normally encountered during the life span of construction materials. At accelerated conditions, samples were immersed in water, simulated acidic rain solution and simulated concrete pore water solution for 28 days. Tensile tests and microstructural analysis were conducted to investigate the impact of different corrosive environments on the bamboo composite material's behavior. The results revealed that the application of epoxy coating successfully protected bamboo composite material's integrity without substantially affecting its mechanical capacity, particularly in acidic environment. Secondly, bond strength between bamboo composite material and concrete was investigated through pull-out tests. The epoxy coating improved the bond strength, especially with addition of sand particles. The findings of this study suggest that epoxy coating can be an effective approach to simultaneously enhance the bamboo composite material's resistance towards acid attack and improve its bond strength with concrete for concrete reinforcement application.

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Keywords: structural reinforcement; bamboo composite; pull-out test; durability; accelerated test

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1. Introduction

Sustainable development is a pertinent concept underlying the growing ecological concern and depleting natural resources. With greater emphasis placed on sustainable and environmentally friendly materials and processes, natural fibres have emerged as promising alternatives to synthetic fibres derived from fossil fuels. Compared to its synthetic counterparts, natural fibres offer substantial advantages such as abundance, cost effectiveness, biodegradability, renewability, ease of processing and many more [1-3]. Drawn to its appeal, much research efforts have been dedicated to incorporating natural fibres in composite materials for diverse applications [3].

Among these natural fibres, special attention should be given to bamboo fibre due to its remarkable strength to weight ratio, resulting in an effective strength on par with low-carbon steel and glass fibre [4, 5]. Furthermore, bamboo culm requires merely 3~6 years of maturity to attain optimal strength suitable for structural application [6].

In virtue of its incredible specific strength and short growth period, application of bamboo fibre in composite as concrete reinforcement offers a promising approach to reduce reliance of construction industry on finite and non-renewable natural resources. However, durability and reliability of bamboo fibre reinforced polymer (BFRP) composite in aggressive environments need to be understood beforehand. Although a study published by *Lima et al.* has provided positive insights on the long-term behaviour of bamboo as reinforcement in alkaline concrete environment [7], the influence of alkaline concrete environment and acid rain on BFRP's performance has yet to be fully explored.

Thus in the current investigation, durability of BFRP was studied by subjecting it to different corrosive mediums normally encountered by materials employed in various civil engineering applications. At accelerated conditions, samples were immersed in water, simulated acid rain solution and simulated concrete pore water solution for 28 days. Effectiveness of readily available epoxy coatings in protecting BFRP from degradation was also studied using Sikadur-31 and Bisphenol A based epoxy. Tensile properties were employed as durability indicators to evaluate the extent of degradation. Additionally, microstructural analysis was conducted to study the microstructural implication of different environments on the composite integrity. With the intent to adopt BFRP as concrete reinforcement, a series of pull-out tests was also carried out to investigate the suitability of the coatings to enhance the bond behaviour of bamboo composite to concrete.

2. Materials and methods

2.1. Bamboo composite fabrication

Dendrocalamus asper species bamboo culm was obtained from Indonesia. Processing and fabrication process of BFRP composite employed in this study were described in detail by *Javadian et al. and Hebel et al.* [8, 9].

2.2. Surface preparation and coating

BFRP composite samples were cleaned with acetone to remove impurities and residual organic matters. Commercially available two component epoxy systems, Sikadur®-31 CF (Sika (Singapore) Pte Ltd), and bisphenol-A resin/amine-based hardener were selected for surface coating of BFRP.

To prepare sand coated BFRP rebar, sand particles with size in between 0.3~1 mm were either manually dispersed in the Sikadur resin before coating, or sprinkled on top of Bisphenol A (BPA) based epoxy coating before curing.

2.3. Accelerated test programme — water, acid, alkaline immersion test

The BFRP specimens were pre-conditioned and exposed to three different environments, which included tap water, alkaline solution and acid solution for 28 days. The acceleration of the pertaining aging tests was achieved through elevated temperature of 60°C or by acidity level far below critical baseline of heavily acidic precipitation (pH <5) [10, 11]. Herein, a much higher concentration of sulfuric acid was adopted due to its relatively high contribution to acid rain [11, 12]. After immersion, samples were quickly rinsed with tap water and post-conditioned