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Probing the hydrophilicity of coir fibres: analysis of the mechanical properties of single coir fibres

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Abstract

This study investigates the mechanical properties of dry versus fully hydrated single micrometre-thick coir fibres. The motivation is to gain insights into the hydrophilicity of the fibres. Specimens of coir fibres were subjected to tensile test until rupture using a horizontal environmental micromechanical tester, mounted on an inverted microscopy for simultaneous microscopy and mechanical testing. The hydrated specimens were submerged in water held in a Petri-dish, mounted onto the tester, for continuous hydration during the test by. Statistical analysis shows strong evidence of differences in the following parameters. The mean fibre diameter of the wet specimens is larger than the dry specimens. The mean tensile stiffness and fracture strength of the dry specimens is larger than the wet specimens. However, the fibre extensibility yields no evidence of differences. A probability strength analysis reveals that while the dry fibre has a higher characteristic strength than the wet fibre, the wet fibre exhibited a smaller spread of variability in strength than the dry fibre.

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Keywords: Coir fibres; fracture strength; extensibility; stiffness; Weibull; probability strength analysis

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There is a growing demand in the commercial use of coconut fibres, particularly the coir fibres, which are derived from the husk of the nut [1–6]. These fibres can be extracted in bundles (Fig. 1 A) from the husk; after subjecting to processing they may then be blended with polymer-based materials to produce a variety of composite materials [1–3], e.g. blending with natural rubber latex for the production of seat cushion parts in automobiles [1–4]. Naturally, this begs the question of the performance of the fibres for engineering applications, especially the capacity of the individual coir fibres (Fig. 1 B) for composite reinforcement under different environmental conditions. In particular, the precise understanding of the following key areas, namely how coir fibres deform and rupture, how fibre-matrix delamination occurs, how the matrix ruptures around the fibre and how the fibre pull-out from the matrix, are still not clear. Owing to the hydrophilic nature of coir fibres [1], one important consideration for using these fibres for reinforcing composites is water absorption. In particular, the humidity in the atmosphere could encourage moisture diffusion into the composite and this could degrade the composite mechanical properties and performance [1,6]. To better understand this effect, we report a study to investigate the mechanics of the single coir fibre in a hydrated state.

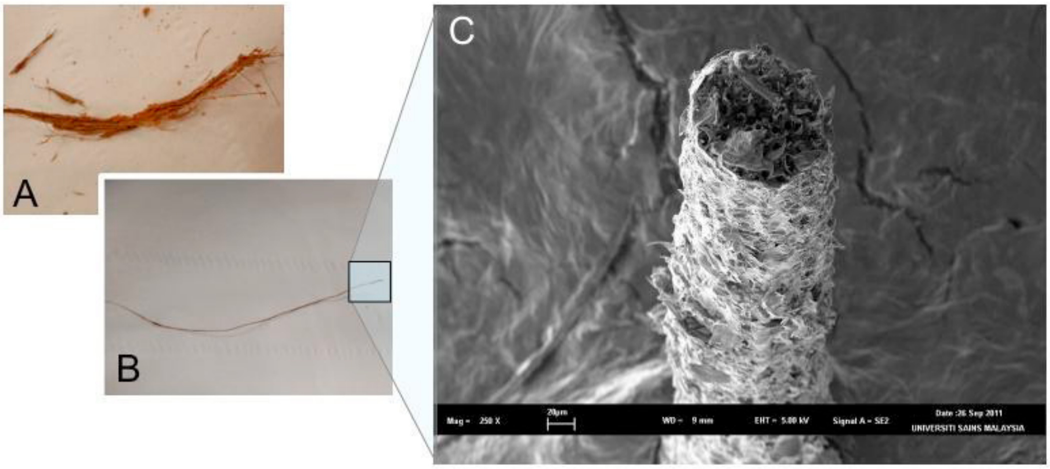

Fig. 1. Coir fibres. (A) A bundle of coir fibre. (B) An isolated single coir fibre. (C) A magnified view of the coir fibre under scanning electron microscope (courtesy of Dr Pooria Pasbaskhsh, Monash University, who obtained the electron micrograph at Universiti Sains Malaysia)

Nomenclature

E	Elastic modulus (stiffness) of the coir fibre
σ_U	Fracture strength of the coir fibre
ε_U	Strain at maximum stress of the coir fibre
σ	Stress in the coir fibre
ε	Strain in the coir fibre
σ_0	Characteristic fracture strength of the coir fibre
β	Modulus of the Weibull distribution
MR	Median rank
n_{spec}	Number of fibre specimens
Pr	Cumulative probability of failure
F	Force generated in the specimen
Δ	Grip-to-grip displacement
A	Cross-sectional area of the specimen
l_0	Nominal length of the specimen (initial grip-to-grip length)