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Optimizing Fibre Length and Treatment Protocols for Enhanced Mechanical Properties of Malaysian Honey Bamboo Composites

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INTRODUCTION

The growing concern over environmental degradation and dependence on non-renewable resources has spurred interest in bio-based composites as sustainable alternatives to synthetic fibre systems. Natural fibre (NF) reinforced polymers are attractive due to their low density, biodegradability, and cost-effectiveness, yet their broader application is often limited by poor fibre–matrix adhesion and inconsistent performance. Bamboo has emerged as a promising reinforcement material because of its rapid growth, availability, and high strength-to-weight ratio. Malaysia alone hosts over 70 bamboo species, though only a fraction have been commercially utilized.

Among them, *Gigantochloa albociliata* (Malaysian honey bamboo) shows encouraging mechanical and thermal properties but remains underexplored for structural bio-composites. While alkali treatments such as NaOH are known to enhance fibre–matrix bonding, the role of fibre length and treatment conditions in optimizing mechanical behavior is less studied. This work investigates how fibre geometry and surface treatment affect the tensile performance of epoxy-based bamboo composites, aiming to establish design insights for sustainable load-bearing applications.

MATERIALS & METHODS

1

RAW Bamboo (G. albociliata)
Epoxy Resin GL311-1
NaOH Pellets
ASTM D638 Moulds

2

Fibre Treatment (6% NaOH, heterogeneous)
Set II (3 CM): 24h @65°C, air-dry
Set III (6 CM): 24h @65°C, oven-dry
Set IV (12 CM): 48h RT, air-dry

3

Composite Fabrication (Hand lay-up, 0°)
Fibre Vf: A:5%, B:10%, C:15%, D:20%
Control: neat epoxy

4

Mechanical Testing (ASTM D638)
Tensile Strength
Young's Modulus
Strain at Failure

RESULTS

Short Fibre Composites (Set II – 3 cm)

- Moderate improvements: σ increased by 4.5–43.2% and E up to +35.1% at 20% Vf.
- Reinforcement was limited as the matrix absorbed more stress.

Medium Fibre Composites (Set III – 6 cm, oven-dried)

- Stronger improvements: σ up to +49.0% and E up to +48.1% at 20% Vf.
- Better fibre dispersion and oven-drying enhanced adhesion.

Long Fibre Composites (Set IV – 12 cm, extended treatment)

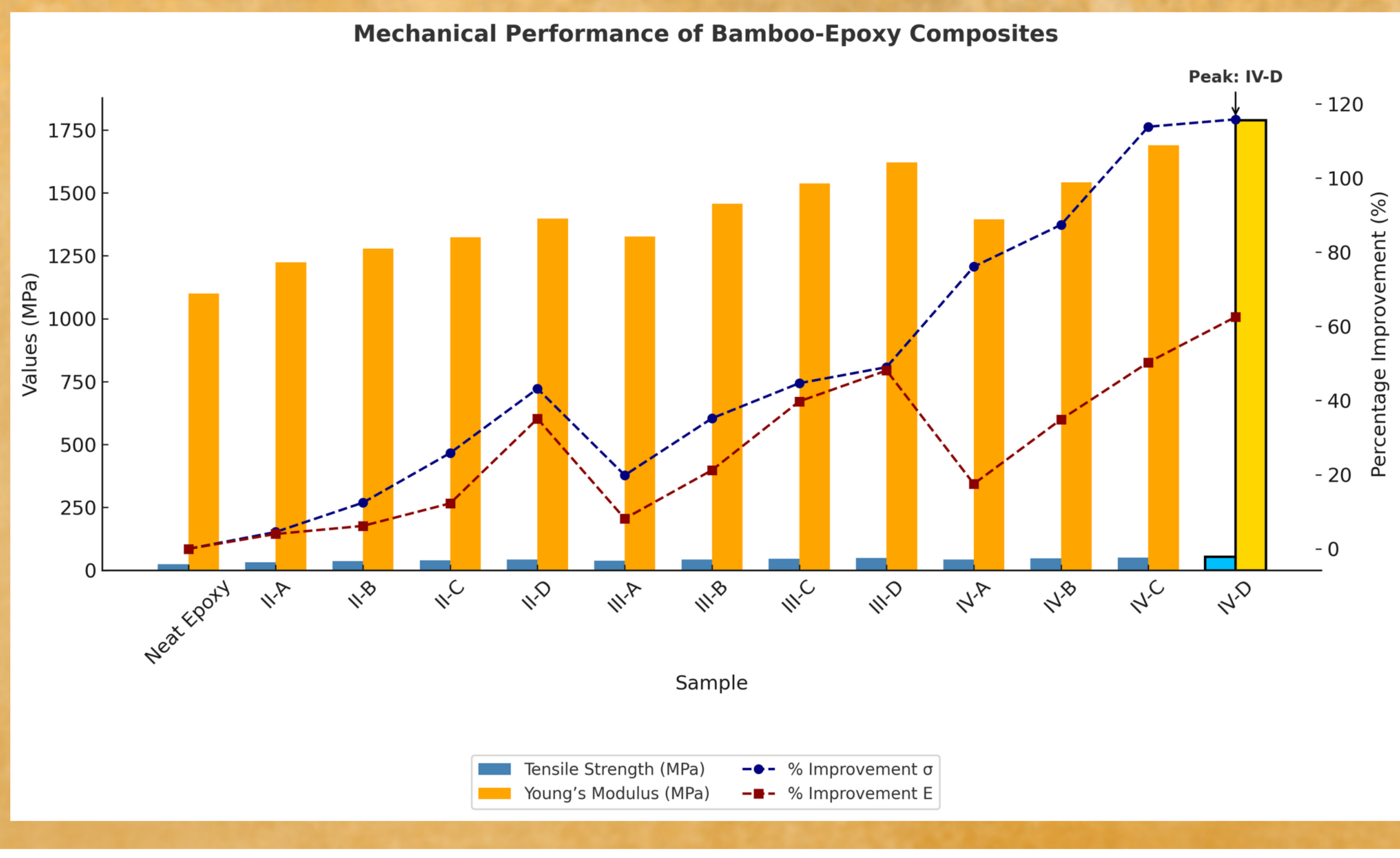
Achieved the highest performance:

- σ = 53.71 MPa (+115.8%)
- E = 1788.1 MPa (+62.6%)

Significantly outperformed neat epoxy (24.9 MPa, 1100.5 MPa) and exceeded benchmarks from prior bamboo–epoxy studies (19-50 MPa).

Ductility Trade-Off

Strain at break decreased from 3.70% (neat epoxy) to 1.98% (IV-D), indicating reduced flexibility due to restricted polymer chain mobility. Despite reduced ductility, toughness improved via fibre pull-out and bridging, enabling effective energy dissipation.



CONCLUSION

Short fibres (II) gave modest reinforcement, while medium fibres (III) showed balanced gains in strength (+49%) and modulus (+48%). Long fibres (IV) delivered the best results:
σ = 53.71 MPa (+115.8%)
E = 1788.1 MPa (+62.6%)
Ductility decreased with fibre reinforcement (ε reduced from 3.70% → 1.98%), reflecting the stiffness–flexibility trade-off. Results confirm Gigantochloa albociliata as a strong candidate for sustainable, high-performance bio-composites in load-bearing applications.

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