CHARACTERISTICS AND BEHAVIOUR OF GOMUTI FIBRE COMPOSITES WITH THERMOSET RESIN

A dissertation submitted by

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ABSTRACT

Gomuti fibre, as a natural fibre obtained from the *Arenga pinnata* tree, is a versatile fibre that has been used conventionally for various purposes such as thatch roofing, water filters, brooms, rope and insulation. Its usage has diminished over time due to the introduction of some more durable, installation-easy and aesthetically pleasing roofing materials such as metal, plastic and concrete. With the current re-emerging interest in natural fibres and their composites as potential building and construction materials, there exists the opportunity to investigate the potential of gomuti fibre.

The main objective of this study is to evaluate the characteristics and behaviour of gomuti fibre composites with polymer thermoset resins, and investigate its feasibility to be developed as a building and construction material. The experimental study covers firstly, the investigation on the strength, stiffness and thermal stability of gomuti fibre itself. Secondly, the strength and stiffness of gomuti fibre composites and thirdly, the impact strength and behaviour of gomuti fibre composites. The experimental results demonstrated the effects of fibre treatment and the use of different thermoset resin matrices on the properties of gomuti fibre. Lastly, a parametric study on the mechanical properties of a flat roof tile was performed to evaluate the feasibility of developing gomuti fibre composites into a building and construction material.

Investigation on the characteristics of gomuti fibre has revealed that gomuti fibre has an average single fibre tensile strength of 173.9 MPa, Young's modulus of 3.85 GPa, and elongation of 12.8 %. The results are particularly comparable with coir fibre. Fibre treatment with sodium hydroxide resulted in increased fibre density, strength, modulus and thermal stability, whilst reducing the diameter. Furthermore, 5

% treatment was found to give the optimal properties although there were no significant variations between the results of 5 % and 10 % treatment amount. Improvement of the properties was observed by treating the fibre with sodium hydroxide however, the results indicated that a higher concentration of sodium hydroxide may damage the fibre causing a reduction in properties.

With variations of fibre treatment and different thermoset resin (polyester, vinylester and epoxy), overall, the tensile strength of gomuti fibre composites was found to be between 28.4 MPa and 48.5 MPa, and Young's modulus between 4.32 GPa and 6.25 GPa. Compressive strengths of the composites were found to be approximately 2–4 times the tensile strengths; the flexural strengths approximately 2 times the tensile strengths, while shear strengths were approximately 0.6–1 times the tensile strengths. The use of different resins resulted in significant variations in the mechanical properties while fibre treatment caused minor variations. The composites with treated fibre show various responses but, overall, improvement was seen on composites with 5 % alkali treated fibre. Results of strength and stiffness evaluation confirm that while fibre treatment has obvious effects to the composite properties, the difference between 5 % and 10 % of NaOH was not significant. This testing result relates to the strength of single fibre. Furthermore, results from mechanical testing indicated that gomuti fibre composites may offer more significant benefits when used for products with low to moderate strength requirements. A similar inference was found on the results of impact testing.

A study of impact strength characteristics of gomuti fibre composites found that, overall, the average impact strength varies from 15 kJ/m^2 to 71.7 kJ/m^2. Samples with untreated fibre exhibited higher impact strength compared to samples with treated fibres, except for 10% NaOH treated fibre with vinylester. Samples with epoxy resin

exhibit lower impact strength compared to samples with polyester and vinylester, except for untreated fibre with epoxy which exhibited higher value compared to samples with vinylester. The higher impact strength relates to inferior fibre-matrix bonding, while lower impact strength can be attributed to better fibre-matrix bonding.

It was found that although strength and stiffness of gomuti fibre composites are below than that of glass fibre, they are comparable to similar natural fibre composites such as coir fibre composites. The functionality of gomuti fibre is considered enhanced when processed into natural fibre polymer composites.

After evaluating the mechanical properties of gomuti fibre composite samples which has provided important assessments of the strength, stiffness and impact strength of the composites, the feasibility of developing gomuti fibre composites into a flat roof tile was studied by parametric design. The results indicated that, with a tile dimension of 330 mm x 420 mm and under the transverse bending loading conditions, the stiffness of tile is the major criteria in the design of a roof tile. A graph was constructed where a design thickness of tile can be obtained based on the value of modulus, or to obtain the values of modulus and design strength based on thickness. By using the graph, it was found that for gomuti fibre composites with a range of modulus from 4.3 to 6.3 GPa, the required minimum thickness is approximately from 13.5 to 15.4 mm and strength of 6.5 to 8.4 MPa.

For the design of gomuti fibre composite roof tile, the stiffness was found to be the governing criteria. While strength criteria is not a governing factors in the design, when the design strength incorporate a safety factor, strength of the composites will become an important criteria. In special cases when a material exhibits high modulus and low strength, design based on the strength is likely to become major criteria.

CERTIFICATION OF DISSERTATION

I certify that the ideas, experimental works, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

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Signature of Candidate Date

ENDORSEMENT

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Signature of Principal Supervisor Date

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Signature of Associate Supervisor Date

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ASSOCIATED PUBLICATIONS

Journal papers

1. Ticoalu, A, Aravinthan, T & Cardona, F 2013, 'A review on the characteristics of gomuti fibre and its composites with thermoset resins', *Journal of Reinforced Plastics and Composites,* vol. 32, no. 2, pp. 124-36.

2. Ticoalu, A, Aravinthan, T & Cardona, F 2013, 'A study into the characteristics of gomuti (Arenga pinnata) fibre for usage as natural fibre composites', *Journal of Reinforced Plastics and Composites*, published online 8 October 2013, DOI: 10.1177/0731684413503191.

3. Ticoalu, A, Aravinthan, T & Cardona, F 2013, 'Mechanical properties of gomuti fibre composites: the influence of fibre treatment and different thermoset resins', (*Under review for publication in journal Composite Structures).*

4. Ticoalu, A, Aravinthan, T & Cardona, F 2013, 'An experimental study on the impact characteristics of gomuti fibre composites' *(Under review for publication in journal Composite Structures).*

Peer-reviewed conference papers

1. Ticoalu, A, Aravinthan, T & Cardona, F 2013, '*A review of current development in natural fibre composites for structural and infrastructure applications', Proceedings of the 2010 Southern Region Engineering Conference (SREC 2010)*, 11-12 Nov 2010, Toowoomba, Queensland, Australia.

2. Ticoalu, A, Aravinthan, T & Cardona, F 2013, 'Experimental investigation into gomuti fibres/polyester composites', *Proceedings of the 21st Australasian Conference on the Mechanics of Structures and Materials (ACMSM 21)*, 7-10 December 2010, Melbourne, Australia.

3. Ticoalu, A, Aravinthan, T & Cardona, F 2013, 'Properties and behaviour of gomuti fibre composites under tensile and compressive load', *Proceedings of the 22nd Australasian Conference on the Mechanics of Structures and Materials (ACMSM 22)*, 11 – 14 December 2012, Sydney, Australia.

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