

EXTERNAL STRENGTHENING OF REINFORCED CONCRETE BEAMS WITH  
BAMBOO FIBER-VINYL ESTER COMPOSITE PLATE

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## ABSTRACT

A research has been conducted to investigate the potential application of natural fiber composite (NFC) fabricated by bamboo fiber embedded with vinyl ester resin matrix (BFRCP) in external strengthening of reinforced concrete (RC) beams. In this study, bamboo fiber were obtained from the Forest Research Institute Malaysia (FRIM) which had been treated with 10% of sodium hydroxide (NaOH) for 48 hours. The bamboo fiber has a density of 0.890 g/cm<sup>3</sup>. In terms of the composite behaviour, the composite plates were tested for physical properties, mechanical properties and thermal properties. The experimental works that carried out in this study were Fourier Transform Infrared Spectroscopy (FTIR), Flexural Test (ASTM D790-03), Tensile Test (ASTM D3039) and Thermogravimetric Analysis (TGA). The BFRCPs were fabricated with different fiber volume ratio (0 %, 10 %, 20 %, 30 %, 40 %) to determine the optimum ratio to be used in strengthening of the reinforced concrete beams. From the composite result, both maximum flexural strength and tensile strength were obtained at the fibre volume ratio of 40 %. The fiber content of composite samples from 10 % to 40 % increased the flexural strength from 104.7 % to 140.9 % compared to the unreinforced neat vinyl ester. Same goes to tensile test, the tensile strength increased from 111.7 % up to 702.7 % with the increases of fiber volume ratio from 10 % to 40 %. The result of FTIR certify that the chemical compositions such as cellulose, hemicellulose and lignin were present in the composite plate and its function were to enhance the adhesion between the fiber and the matrix. The TGA test revealed that the exact thermal decomposition temperature of bamboo fiber - vinyl ester composites was at 320°C. For the structural behaviour, four-point loading tests was carried out to study the behaviour of the RC solid beams as well as RC beams with circular openings. The study shows that the strength of the beam strengthened with bamboo fiber - vinyl ester composite plate increased by 2.0 % in RC solid beam and 77.8 % in RC beam with circular opening when compared to the un-strengthened beams. In the case of cracks, the bamboo fiber-vinyl ester composite plate had diverted the cracks to appear on the edge of the plate for RC solid beam and minimal the propagation of diagonal cracks were traced in RC beam with circular openings. Therefore, it is concluded that the bamboo fiber-vinyl ester composite plate is effectively to be used as an external strengthening material for strengthening of RC beams.

## ABSTRAK

Satu kajian telah dijalankan untuk mengenai potensi penggunaan komposit yang diperbuat daripada gentian buluh sebagai gentian semula jadi baru bersama matriks resin vinil ester (BFRCP). Dalam kajian ini, gentian buluh diperolehi dari pihak Institut Penyelidikan Perhutanan Malaysia (FRIM) yang telah dirawat dengan 10% natrium hidroksida (NaOH) dalam masa 48 jam. Gentian buluh mempunyai ketumpatan 0.890 g/cm<sup>3</sup>. Plat komposit telah diuji dalam segi fizikal, mekanikal dan haba. Kerja-kerja ujikaji yang dijalankan dalam kajian ini adalah Fourier Transform Infra-Merah Spektroskopi (FTIR), Ujian Lenturan (ASTM D790-03), Ujian Tegangan (ASTM D3039) dan Thermogravimetric Analisis (TGA). BFRCPs telah difabrikasi dengan nisbah isipadu gentian yang berbeza (0%, 10%, 20%, 30%, 40%) bagi menentukan nisbah optimum untuk digunakan dalam mengukuhkan rasuk konkrit. Kedua-dua maksimum kekuatan lenturan dan kekuatan tegangan telah diperolehi pada nisbah isipadu gentian 40%. Kandungan serat sampel komposit dari 10% ke 40% telah meningkatkan kekuatan lentur dari 104.7% sehingga 140.9%. Begitu juga dengan ujian tegangan, kekuatan tegangan meningkat dari 111.7% sehingga 702.7% dengan peningkatan nisbah serat sampel dari 10% ke 40%. Keputusan FTIR mengesahkan bahawa kandungan kimia seperti selulosa, hemicellulose dan lignin turut hadir pada plat komposit dan fungsinya adalah untuk meningkatkan lekatan di antara gentian dan matriks. Ujian TGA mendedahkan tepat penguraian haba suhu serat buluh – vinil ester adalah pada 320° C. Ujian empat mata titik beban telah dijalankan untuk mengkaji kelakuan rasuk konkrit pepejal serta rasuk konkrit bukaan bulat. Kajian mendapati bahawa kekuatan rasuk yang diperkuatkan dengan serat buluh - vinil ester plat komposit meningkatkan sebanyak 2.0% pada rasuk konkrit pepejal dan 77.8% pada rasuk konkrit dengan bukaan bulat. Dalam pemerhatian retak, buluh gentian-vinil ester plat komposit telah mengalihkan retak untuk muncul di pinggir plat komposit pada rasuk konkrit pepejal dan memperlahankan penyebaran retak pada rasuk konkrit dengan bukaan bulat. Oleh itu, ia membuat kesimpulan bahawa buluh gentian-vinil ester plat komposit adalah berkesan untuk digunakan sebagai bahan pengukuhan luaran untuk memulihkan rasuk konkrit.