# STRENGTHENING OF RC BEAM EXTERNALLY USING BAMBOO FIBRE REINFORCED COMPOSITE: A STUDY ON *GIGANTOCHLOA SCORTECHINII*

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## SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor Degree of Civil Engineering

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**STUDENT'S DECLARATION**

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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# ABSTRAK

Penggunaan polimer bertetulangan gentian semula jadi sebagai pengukuh kepada struktur konkrit secare luaran amat diperlukan untuk menjalankan kerja pemulihan bangunan. Satu kajian mengenai Gigantochloa Scortechnii (Buluh Semantan) telah dijalankan untuk menyelidik sifat mekanik buluh dan seratnya untuk digunakan dalam fabrikasi komposit. Dalam kajian ini, buluh diperoleh dari Raub, Pahang. Dari segi sifat mekanik buluh, ujian tegangan dan mampatan antara spesimen dalam keadaan mentah dan kering telah dilakukan. Di samping itu, serat buluh telah dirawat dengan 10 % natrium hidroksida (NaOH) selama 48 jam untuk digunakan dalam fabrikasi plat komposit. Serat buluh dengan ketumpatan 0.75 g/cm$^3$ dicampur dengan matriks resin epoksi dalam nisbah 2: 3. Kemudian, ujian kekuatan tegangan dan lenturan dijalankan untuk membandingkan ciri-ciri antara plat komposit epoksi dengan 0 % (neat epoxy) dan 40 % serat (BFECP). Kemudian, penglekatan BFECP kepada rasuk konkrit bertetulang sebagai penguat luaran. Ujian pemuatan empat mata dilakukan untuk mengkaji ciri-ciri perubahan struktur antara kawalan (CB), tanpa pengukuhan (USTB) dan pengukuhan (SSTB). Hasil ujian eksperimen menunjukkan bahawa beban muktamad untuk rasuk dengan pengukuhan adalah 16.81 % dan 23.84 % lebih tinggi daripada rasuk kawalan dan rasuk yang tanpa pengukuhan. Dari segi penubuhan retak, retakan lenturan didapati pada spesimen rasuk di bahagian tengah manakala rasuk kawalan gagal dalam ketegangan pepenjuru. Selain itu, keputusan eksperimen menunjukkan bahawa kekuatan tegangan dan mampatan spesimen buluh kering adalah lebih tinggi daripada keadaan mentah, iaitu 48.77 % dan 31.68 %. Sehubungan dengan itu, didapati bahawa BFECP adalah 309.73 % dan 820.11 %, lebih tinggi daripada epoksi kemas dari segi kekuatan tegangan dan lenturan. Secara kesimpulannya, plat komposit epoksi buluh mempunyai potensi untuk digunakan sebagai bahan pengukuhan alternatif untuk polimer bertetulang sintetik.

# ABSTRACT

The use of fibre reinforced polymer as external strengthening in reinforced concrete (RC) structures which in need to carry out rehabilitation works. A study on *Gigantochloa Scortechnii (Buluh Semantan*) has been conducted to investigate the mechanical properties of the bamboo and its fibres to be used in composite fabrication. In this research, the bamboos are obtained from Raub, Pahang. In terms of mechanical properties of bamboo, tensile and compression test between the raw and oven-dried bamboo specimens have been performed. On the other hand, for the composite plate fabrication, the bamboo fibres had been treated with 10 % of sodium hydroxide (NaOH) for 48 hours. The bamboo fibres with a density of 0.75 g/cm$^3$ are mixed with epoxy resin matrix in the ratio of 2:3. Tensile and flexural strength tests are executed to compare the characteristics between the neat epoxy and bamboo fibre-epoxy composite plate (BFECP). Moreover, the BFECP is bonded to the reinforced concrete (RC) beam as external strengthening material. Four-points loading test is performed to study the structural behaviour between the control (CB), un-strengthened (USTB) and strengthened beam (SSTB). From the results, the tensile and compressive strength of the oven-dried bamboo specimens are higher than in raw condition, which is 48.77 % and 31.68 %, respectively. Meanwhile, the BFECP are 309.73 % and 820.11 %, respectively, greater than neat epoxy in terms of tensile and flexural strength. On the other hand, the ultimate load sustained by the strengthened beam is 16.81 % and 23.84 % higher than control beam and un-strengthened beam, respectively. In terms of crack propagation, the flexural cracks were found in the mid-span of beam specimens while only control beams failed in bending and experienced diagonal tension failure. This signifies that bamboo fibres-epoxy composite plate has potential to be used as an alternative strengthening material for synthetic reinforced polymer.

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# LIST OF SYMBOLS

| | |
|---|---|
| % | Percentage |
| mm | Millimetre |
| $g/cm^3$ | Gram per centimetre cube |
| mL | Millilitre |
| N | Newton |
| kN | Kilo Newton |
| kN/sec | Kilo Newton per second |
| °C | Degree Celsius |
| g | Gram |
| mm/min | Millimetre per minute |
| $mm^2$ | Millimetre square |
| MPa | Mega Pascal |
| P | Load |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| ASTM | American Society for Testing and Materials |
| BFERP | Bamboo Fibre-Epoxy Reinforced Composite Plate |
| FRP | Fibre Reinforced Polymer |
| FKASA | Faculty Civil Engineering & Earth Resources Laboratory |
| LVDT | Linear Variable Displacement Transducer |
| NaOH | Sodium Hydroxide |
| RC | Reinforced Concrete |
| UTM | Universal Testing Machine |

# CHAPTER 1

# INTRODUCTION

## 1.1 Research Background

Bamboo is the world's fastest growing woody grass. It grows four feet in a 24 hours period. There are about 1200 species of bamboos and most of them grow in Asia, Africa and Latin America. Bamboo can withstand more tension compared to compression as the bamboo fibres run axially are of highly elastic vascular bundle that has a high tensile strength and comparable with steel. However, due to its low natural durability, it requires to be chemically treated (Sharma, Dhanwantri and Mehta, 2014). Potential usage of bamboo fibre as reinforced composite material is proven in the available studies. Bamboo has a high percentage of amorphous lignin and cellulose which are approximately 10.15% and 73.83%, respectively. This high lignin content makes bamboo fibre brittle compared to other natural plants. However, bamboo fibre is comparable with glass fibre in term of environmental sustainability, mechanical properties and recyclability (Zakikhani *et al.*, 2014).

Fibre reinforced composite (FRC) is also known as fibre reinforced plastic (FRP). Fibre reinforced polymer materials are composites which consist of two major components: high strength fibres reinforcement and polymeric matrices. There are innumerable of distinct sets of properties from combining different fibres and resins. The fibres in these materials are elements that carry loads while providing strength and rigidity. The polymer matrices play their role in conserving the fibre arrangement (position and orientation) and preventing them from any environment and possible damages (Begum and Islam, 2013). Since natural fibres have a lot of favourable properties compared to synthetic fibres like handling and disposal process which lead to environmental issues. Therefore, the application of natural fibres in reinforced composite plate has increased tremendously in taking over the usage of synthetic fibres such as glass and carbon fibre.

The matrix material used to bind the fibre reinforcement, it shaped the composite component and determines the surface quality. It is also responsible for the load transfer and contribute to environmental protection. A matrix can be polymeric, ceramic or metallic. Polymer matrices are extensively used for composites in commercial. Polymers that are classified as plastics can be divided into two major categories based on their elevated temperature characteristics, which are thermoplastic and thermosetting. A thermoplastic material will flow at elevated temperatures, which also known as crystalline melting point and the solidified polymer can be remodelled several times as necessary by repeating heating and cooling without causing any chemical changes. While thermosetting polymers will not be able to flow upon reheating once they have been successfully moulded by plastic flow at elevated temperature. Although thermoplastic requires a longer time to be produced, but it is easier to mould compared to thermosetting plastic (Hameed, 2012). However, in structural engineering application, thermosetting polymers are widely used as the behaviour of thermoset that unable to be deformed easily as the polymer chains are interlinked. Thermosetting resins that commonly used in binding the fibres to form composite plate are polyester resin, epoxy resin and vinyl esters resin (Chandra Das and Haque Nizam, 2014). In this study, epoxy is used as the matrix in fabricating the bamboo fibre reinforced composite plate.

The use of fibre reinforced polymer as external support of reinforced concrete (RC) structures which in need to carry out rehabilitation works. Those rehabilitation and strengthening works, including maintenance of deteriorated structures, damaged structures due to seismic actions such as earthquake, defective in design stage, such as under designed structures where in need of extra strengthening, and to achieve the stringent design requirement (Chandra Das and Haque Nizam, 2014). Natural fibre such as bamboo fibre used as structural reinforcements in composite as a substitution of synthetic fibre, the weight of the composite is reduced about 10-30% and with outstanding acoustical absorption properties (L.S, Reddy and Nizar, 2013).

## 1.2 Problem Statement

Malaysia is a densely forested country and forest products such as bamboo, timber and rattan are important sources of income. The potential of growth of the bamboo industry is enormous which has been recognized by researchers. In the last decade, the bamboo development has become the first concern of Forest Research Institute Malaysia (FRIM) in terms of growth and the manufacturing aspects. In Malaysia, there are about 70 species of bamboo where 50 are in Peninsular Malaysia, 30 in Sabah and 20 in Sarawak. The 10 available genera are *Bambusa*, *Chusquea*, *Dendrocalamus*, *Dinochloa*, *Gigantochloa*, *Phyllostachys*, *Racemobambos*, *Schizostachyum*, *Thyrsostachys* and *Yushania* (Azmy and Appanah, 1991).

Strengthening techniques are required for the deteriorated structure to prolong the service period of the building instead of demolition of it. Therefore, the utilization of FRP becomes one of the best choices in supporting the structures externally. This is because synthetic fibres like carbon, glass and aramid yield high strength-to-weight ratio, high strength and stiffness, simple installation and long fatigue life (Dong, Wang and Guan, 2013). However, synthetic fibres are slowly replaced by the use of natural fibres in the production of fibre reinforced polymer composite. Synthetic fibres are less cost effective, poor recycling and non-biodegradable properties which rise negative impacts to the environment (Begum and Islam, 2013).

Natural fibres are more reliable, sustainable, biodegradable and environmental friendly which able to substitute synthetic fibres as structural reinforcement materials due to the increasing environmental concern and public awareness of industrial pollution. Some of the natural fibres are bamboo, sisal, jute and hemp, they have low density with high specific strength and stiffness properties, cost efficient, renewable, and accessible globally (Ku *et al.*, 2011). Hence, with the usage of natural fibres, the environmental problems can be reduced by diminishing the emission of pollutants and greenhouse gas while enhancing the energy recovery. Besides, the application of natural fibres as reinforcement material fabricates with polymeric matrices can enhance their mechanical properties including tensile, flexural and impact properties (Braunschweig, 2016).

The polymeric resin acts as a fibre protection and impede the diffusion process. Hence, mechanical properties of the composite plate are important to investigate the

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