EXTERNAL STRENGTHENING OF RC BEAMS USING *GIGANTOCHLOA LEVIS (BULUH BETING)* FIBER REINFORCED COMPOSITE PLATE

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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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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

Dalam pengajian semasa, penggunaan gentian buatan manusia merupakan kaedah yang cekap untuk megukuhkan struktur secara luaran. Namun begitu, kos pembuatan yang tinggi serta pencemaran alam sekitar telah meningkatkan kesedaran orang awam terhadap isu ini. Belakangan ini, gentian semula jadi telah menjadi bahan yang menarik perhatian penyelidik untuk menjalani kajian secara mendalami untuk mencungkil kemungkian menjadikan gentian semula jadi sebagai pengganti untuk gentian buatan manusia. Satu kajian telah dijalankan untuk mengkaji potensi penggunaan komposit yang diperbuat daripada gentian buluh dan matriks resin epoxy (BFRCP). Gentian buluh yang digunakan dalam kajian ini diperolehi daripada Raub, Pahang. Buluh mentah dan buluh kering telah dikaji dalam segi mekanikal dan fizikal. Kerja uji kaji yang dijalankan dalam segi mekanikal adalah ujian mampatan dan ujian tegangan. Selain itu, plat komposit telah diuji dalam segi mekanikal, iaitu ujian tegangan (ASTM D3039) dan ujian lenturan (ASTM D790-03). BFRCPs telah difabrikasi dengan nisbah isipadu gentian 0% dan 40%. Ujian empat mata titik beban telah dijalankan untuk mengkaji kelakuan rasuk konkrit bertetulangan yang mempunyai tetulang rangkai yang penuh dan tanpa tetulang rangkai di bahagian lentur rasuk. Berdasarkan hasil kaji, buluh kering mempunyai kekuatan mekanikal yang lebih tinggi berbanding dengan buluh mentah. Namun begitu, kekeringan buluh yang terlampau akan mengganggu kekuatan mekanikalnya. Manakala bagi kajian terhadap plat komposit. Kenaikan kekuatan tengangan sebanyak 374.59% bagi plat komposit bergentian dibanding dengan plat epoxy tulen. Manakala penambahbaikan plat bergentian sebanyak 750.60% dalam segi kekuatan lenturan berbanding dengan plat epoxy tulen. Berdasarkan hasil kajian daripada ujian empat mata titik beban, didapati rasuk konkrit tidak bertetulang yang tidak diperkuatkan (UNST) mempunyai kemerosotan kekuatan sebanyak 6.72% berbanding dengan rasuk konkrit yang mempunyai tetulang rangkai yang penuh. Di samping itu, rasuk konkrit tidak bertetulang yang diperkuatkan (ST) mempunyai kenaikan kekuatan sebanyak 9.30% dan 10.63% berbanding dengan UNST. Selain itu, rasuk yang diperkukuh mampu menampung kekuatan yang sama dengan rasuk yang mempunyai tetulang rangkai penuh. Dari segi retakkan rasuk, rasuk yang diperkukuhkan didapati mempunyai retak di bahagian pinggir plat komposit. Kesimpulannya, pengukuhan luaran rasuk konkrit bertetulangan dengan penggunaan buluh gentian – epoxy komposit didapati berkesan dan berpotensi menggantikan komposit gentian buatan manusia.

ABSTRACT

Synthetic fiber reinforced polymer (FRP) composite is an efficient method for strengthening of reinforced concrete (RC) externally. Unfortunately, the non-renewable, high cost production and environmental harmful of synthetic fibers had increased public awareness towards this issue and hence inevitable arisen the uses of renewable resources. A research had been conducted to investigate the potential of application of bamboo fiber reinforced composite plate (BFRCP) in external strengthening of RC beam. The bamboo fibers used was *Gigantochloa Levis*, also known as *Buluh Beting* which were obtained from Raub, Pahang. Mechanical behaviour of raw and dried bamboo was tested with compression and tensile tests. Besides, the composite plates with 0% and 40% fiber volume were tested for tensile test (ASTM D3039) and flexural test (ASTM D790-03) to identify the mechanical properties. Four-point loading test was conducted to investigate the structural behaviour of RC beams. Based on the result of the mechanical behaviour of bamboo, the dried bamboo showed higher mechanical strength as compared with the raw bamboo. However, the over-dried bamboo will affect the mechanical result. In terms of the composite behaviour, there was an increment of 374.59% of average ultimate tensile strength of fiber reinforced composite as compared to the un-reinforced composite. Whereas, for flexural test, the average ultimate strength of fiber reinforced composite was 11.76 times or 750.60% more than the neat epoxy sample. In terms of structural behavior, it was found that the un-strengthened beam without the shear link in the flexure zone (UNST) has shown a reduction in ultimate load of about 6.72% as compared to the control beam (CB). Whereas, two beams without the shear link in the flexure zone strengthened using BFRCP (ST) had an increment of 9.30% and 10.63% in terms of beam capacity as compared to beam UNST. Besides, both the strengthened beams, ST proven the capability to restore the load carrying capacity of the control beam. In terms of crack pattern, the BFRCP had diverted the cracks from the flexure zone to the edge of the plate for RC beam. Hence, this signifies that BFRCP has potential to be used as an alternative external strengthening material to the synthetic composite plate.

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LIST OF SYMBOLS

%	Percentage
mm	Millimetre
g/cm^3	Gram per centimetre cube
N	Newton
kN	Kilo Newton
ºC	Degree Celcius
g	Gram
mm^2	Millimetre square
MPa	Mega Pascal

LIST OF ABBREVIATIONS

ASTM	American standard testing manual
BFRCP	Bamboo fiber reinforced composite plate
BFRECP	Bamboo fiber reinforced epoxy composite plate
CNT	Carbon nanotube
FRP	Fiber Reinforced Polymer
LVDT	Linear variable displacement transducers
NaOH	Sodium hydroxide
NFRC	Natural fiber reinforced composite
RC	Reinforced concrete
UTM	Universal Testing Machine

CHAPTER 1

INTRODUCTION

1.1 Research Background

Fiber reinforced polymer (FRP) is a mixture of high strength fibers embedded in a polymer matrix to produce composite material. Commonly, synthetic fibers like carbon and glass are widely used in fabrication of FRP. The fibers are mainly contributing the mechanical properties, whereas polymer matrix responsible for the protection from environmental attack. The resultant composites are used in a range of industries including sporting, leisure, aerospace, automotive and construction (Gurunathan, Mohanty and Nayak, 2015). However, synthetic FRPs have problems in disposing as they do not decompose naturally in the ground. Owing to the fact that FRP had brought environment and sustainability issues, at a recent time, public attention has gone to green materials such as natural fibers as a resource in the field of polymer science through introduction of bio composites (Yildizhan, 2018). Bio-composites, also known as biodegradable composites is a sustainable material with eco-friendly natural fibers are used to replace the synthetic fibers. Moreover, bio-composites help to reduce raw material usage, reduce non-renewable waste as well as cut fossil-fuel consumption.

There are various types of natural fiber which included cellulose based, animal and mineral. For plant or cellulose based fiber, it is divided into different groups according to their function. Bamboo fiber was chosen as the filler because bamboo is a commonly found natural resource in Asia and South America. The mechanical properties of bamboo are relatively high and are comparable to those of wood. It has been traditionally used to build a variety of furniture and living tools. Furthermore, it takes only 6-8 months to grow to its mature size, whereas wood takes about 10 years. Fiber longitudinally aligned in its body provide high strength with respect to its weight which contribute the title of ‘natural glass fiber’(Okubo, Fujii and Yamamoto, 2004). The high cellulose content with moderate content of lignin approximately 32% and micro-fibrillar angle is relatively small which is 2°–10° contributed to the tensile strength and proportional to the modulus of elasticity. Hence bamboo fiber is suitable to be used as fiber reinforcement in different matrix (Tong *et al.*, 2017).

Matrix acts as the binding material which bind with fibers to form a composite plate. There are two types of matrix: thermoplastic and thermosetting. Thermoplastics are a plastic polymer material that changes properties when subjected to different temperature. Thermoplastics become soft when heat is applied and have a smooth, hard finish when cooled. It becomes moldable when exceeding a specific temperature and solidifies upon cooling. Meanwhile, thermosetting polymers are liquid state at room temperature prior curing. After undergoing heat treatment, it is in solid state and unable to re-hot deformable due to the difficulty in reforming. Most structural engineering applications used thermosetting plastics for applications as the thermosetting plastics are more advanced over thermoplastics if they are compared to both. Generally, thermosetting plastics are stronger than thermoplastic materials due to the strong covalent bonds between polymer chain that hard to break. Besides, thermosetting has a high crosslink density that provides a good thermal stability and resistance to chemical attack. Thermosetting that usually used for fabrication of composite plate are epoxy resin, vinyl ester resin and polyester resin (Chandra Das and Haque Nizam, 2014). Epoxy resin was used as the matrix to fabricate the bamboo fiber reinforced composite plate in this study.

Therefore, FRP has become more preferable to be used as the external strengthening material instead of rebuilding the structure. The low specific weight, low production cost and high strength of the natural FRP are the attractive features that may replace the synthetic FRP. Hence, retrofitting damaged structures by providing extra strengthening on it is the easiest and convenient method which helps to increase the service period of the structure.

1.2 Problem Statement

Over the last three decades, application of FRP is getting more popular, especially in the construction industry. The high strength-to-volume and high stiffness of synthetic reinforced fibers are the main reasons being chosen as the reinforced fibers (Dong, Wang and Guan, 2013). However, the cost of fabrication of synthetic fiber reinforced composite plate is much higher compared to the natural fiber reinforced composite plate. Moreover, the main drawback of synthetic reinforced composite plate is non-biodegradable properties which bring a serious adverse effect on the environment.

Non-renewable resources are becoming scarce which had increased public awareness towards this issue and hence inevitable arisen the uses of renewable resources (Faruk *et al.*, 2012). Natural fiber reinforced composites (NFRC) as a replacement for polymer-matrix composite, such as glass of carbon fiber reinforced plastics (GFRP/CFRP) have received considerable attention from public recently. In addition, it is reported that a target was set by US Department of Agriculture (USDA) and the US Department of Energy (DOE) which is the implementation of 10% of basic chemical building blocks replace with renewable resources by 2020 and aimed to increase to 50% by 2050 (Gurunathan, Mohanty and Nayak, 2015). Natural fibers are biodegradable, recyclable and economical in the manufacturing process compared to synthetic fibers. Moreover, natural fibers are low density and high mechanical strength which are better than the traditional reinforcements. Bamboo fiber also known as “natural glass fiber” is capable to be the reinforced fibers in polymeric composite material because of the high specific strength and stiffness which are comparable with glass fibers (Zakikhani *et al.*, 2014).

1.3 Research Objectives

The purpose of this study is to determine the potential use of *Beting* bamboo fiber reinforced composite plate (BFRCP) in external strengthening of reinforced concrete beam. The following are the objectives set in this study:

1. To determine the mechanical properties of *Beting* species of bamboo.

2. To determine the mechanical properties *Beting* bamboo fiber composite plate as external strengthening material.

3. To evaluate the structural behaviour of RC beams strengthened in flexure using bamboo fiber composite plate.

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