STUDY ON REINFORCED CONCRETE BEAMS STRENGTHENED EXTERNALLY USING MENGKUANG LEAVES-EPOXY COMPOSITE PLATE

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Thesis submitted in fulfilment of the requirements
for the award of the degree of
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LIST OF SYMBOLS

%	Percentage
mm	Millimeter
g/cm^3	Gram per centimetre cube
MJ/t	Minecraft Joules per time
mL	Milliliter
N	Newton
kN	Kilo Newton
℃	Degree Celsius
g	Gram
mm/min	Millimetre per minutes
mm^2	Millimeter square
MPa	Mega Pascal

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
CFRP	Carbon fiber reinforced plate
DMC	Dough with chopped glass fiber
FRP	Fiber reinforced plate
LVDT	Linear Variable Differential Transducer
MLRCP	Mengkuang leaves reinforced composite plate
NaOH	Sodium hydroxide
NFRC	Natural fiber reinforce composite
RC	Reinforced concrete
SEM	Scanning electron microscope
SMC	Sheets with longer fibers
UTM	Universal Testing Machine

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ABSTRACT

Synthetic fiber usage in reinforcing composite plate for variety of applications is a common practice on advance engineering structures such as automobiles and infrastructure in bridges and buildings. Study on using natural fiber as replacement to synthetic fiber was carried out for recent decades to investigate the potential use of natural fiber composite plate in strengthening of reinforced concrete (RC) structures as an alternative to synthetic fiber reinforced composite plate. A study has been carried out to investigate the potential use of mengkuang leaves-epoxy composite for the strengthening of reinforced concrete beams. Mengkuang leaves were treated sodium hydroxide (NaOH) in concentration of 2 %, 5 % and 8%, examined by using scanning electron microscope (SEM) and single fiber test, while composite plates were tested for flexural strength and used as external strengthening material on RC beams and tested under four-point bending test. Fiber volume fraction of 10 % - 40 % reinforced with epoxy were considered in this study. SEM micrographs showed that alkali treatment gives no significant effect on the leaves surfaces, the inner layer which consists of fiber was undefined. Experimental results showed that the tensile strength for untreated samples were found higher than treated samples and lower tensile strength was obtained as NaOH increases. Flexural strength of composites increases as fiber volume fraction increases from 10 % to 30 %. Fiber volume fraction of 30 % gives the most optimum results which improve the flexural strength about 96 % higher than the unreinforced epoxy plate. In terms of four-point bending test, the results showed that RC beams strengthened using mengkuang leaves-epoxy reinforced composite plate can sustained higher load capacity than the control beam and reduced the beam deflection. The increased in ultimate load varied from the range of 7 % to 13 % while the beam deflection reduced from 17 % to 38 %. In terms of crack pattern, vertical flexural cracks were found along the tension zone in the mid-span of the control beam. The control beams failed in bending. On the other hand, mengkuang leaves-epoxy reinforced composite plate has diverted the cracks that initially formed in the midspan of the beams to the edge of the plate causing the formation of diagonal shear cracks that propagated towards the point load of the beams. The mode of failure for mengkuang leaves-epoxy reinforced composite plate in strengthening RC beams were in bending with the peeling of composite plate. This signifies that mengkuang leaves-epoxy composite plate has potential to be used as an alternative external strengthening material to synthetic composite plate.

ABSTRAK

Penggunaan serat buatan manusia merupakan amalan biasa diamalkan dalam pelbagai aplikasi yang berkaitan dengan struktur seperti jambatan dan kereta. Belakangan ini, serat semula jadi menjadi bahan yang menarik perhatian penyelidik untuk menjalani kajian secara mendalami untuk mencungkil kemungkian menjadikan serat semula jadi sebagai pengganti untuk serat buatan manusia. Kajian telah dijalankan untuk mengenai potensi komposit yang diperbuat daripada daun mengkuang sebagai gentian semula jadi baru ke dalam matriks resin epoxy. Daun mengkuang dirawat dengan 2 %, 5 % dan 8 % natrium hidroksida (NaOH) dan dihantar ke makmal untuk menggunakan mikroskop elektron pengimbas (SEM) dan ujian serat tunggal, manakala plat komposit telah diuji untuk kekuatan lenturan dan digunakan untuk mengukuhkan rasuk konkrit dan menjalankan eksperimen empat titk beban. Kandungan serat dari 10 % hingga 40% telah dikaji dalam kajian ini. SEM mikrograf menunjukkan bahawa rawatan alkali tiada kesan yang besar ke atas daun permukaan, lapisan dalam yang mengenai serat tidak dapat dibaca. Keputusan eksperimen menunjukkan kekuatan tegangan daun mengkuang yang tidak dirawat dengan NaOH lebih tinggi berbanding dengan daun mengkuang yang dirawat dengan NaOH. Kekuatan lenturan rencam bertambah apabila Kandunguan serat dalam plat komposit bertambah sehingga 30 %. 30 % gantian resin epoxy untuk plat menunjukkan keputusan yang optimum dan meningkatkan kekuatan lenturan sebanyak 96% berbanding plat resin epoxy yang tiada gentian. Untuk ujian empat titik beban, keputusan menunjukkan bahawa mengukuhkan rasuk dengan plat komposit daun mengkuang akan meningkatkan kapasiti beban dari 7 % kepada 13 %. Rasuk pesongan mengurangkan dari 17 % kepada 38 %, menunjukkan keputusan yang positif. Kajian berkenaan daun mengkuang haruslah dijalani secara dalami untuk menambahbaikan plat yang diperbuat menggunakan daun mengkuang sebagai altenatif serat semula jadi lain.

CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

Fiber reinforced polymer (FRP), also known as fiber-reinforced plastic, is a specific type of two-component composite material consisting of high strength fibers embedded in a polymer matrix. The mechanical and physical properties are clearly controlled by their constituent properties and by the micro-structural configuration. At the early stage, synthetic fibers such as carbon, glass and aramid are used in manufacturing FRP. While the fibers are mainly responsible for strength and stiffness properties, the polymeric matrix contributes to the load transfer and provides environmental protection. Matrix can be divided into two parts: thermoplastic and thermosetting. Thermoplastics are amorphous polymers, which can be modified into different shapes without changing the molecular structures at elevated temperature. Also, thermoplastics can be remolded by heating and cooling the thermoplastic repeatedly without changing the molecular structures. On the other hand, thermosetting polymers cannot be heated to reform the shape of the polymers. Due to the properties of thermosetting polymers that unable to be deformed easily, thermosets are in used to apply at most of the structural engineering applications. Compared to thermoplastic, thermosets have good thermal stability at service temperatures, good chemical resistance and display low creep and relaxation properties. The types of thermosetting resins commonly applied in the manufacture of composite plate are: polyester resin, epoxy resin and vinylesters resin (Das & Nizam, 2014).

Application of FRPs often occurred on the advance engineering structures, with their usage ranging from aircraft, helicopters and spacecraft to boats, ships and offshore platforms and to automobiles, sports goods, chemical processing equipment and civil infrastructure such as bridges and buildings (Masuelli, 2013). Due to the advantages of FRP in terms of high strength, lighter weight and easier to be applied, most of the buildings that require extra strengthening or rehabilitation will select external strengthening using FRPs instead of rebuild after demolition. The structures that in need of rehabilitation are as following (Das & Nizam, 2014) : experienced seismic reaction such as earthquakes, deterioration of concrete structures due to ageing, change in use of the building structures, such as changing from shopping outlets to parking level, and error during design stages, for example, the structures are under designed and in need of extra strengthening. Thus, this strengthening techniques retrofitted damaged structured by providing extra strengthening on it and lengthen the service period in an easy and convenient method.

1.2 PROBLEM STATEMENT

Applications of FRP are widely in used and getting popular over last decades. As mentioned before, synthetic fibers such as carbon and glass are used due to high strength-to-volume ratio, flexible and high stiffness (Dong et al., 2013). However, the production costs of synthetic fiber composite plates are not cost effective and health will be affected during the production of FRP.

Natural fibers are then become an attracting and potential materials to replace synthetic fibers recently. Several types of natural fibers are studied and carried out experiment to test on their mechanical properties. Among the natural fibers, kenaf fibre has higher tensile strength compared to other natural fibers (Ku et al., 2011). Natural fibres are preferred over synthetic fibers when high load bearing capacity is not required. Besides, natural fibers are degradable, low cost in production and harmless to health. Mechanical properties of the matrices such as tensile, flexural will be increases with the use of natural fiber reinforcing in polymer (Yan et al., 2016). Thus, the use of natural fibers will decrease the content of polymer and providing significant positive outcome than neat polymer.

In Malaysia, mengkuang leaves or *pandanus atrocarpus*, also known as screw pine in English, belongs to Pandanaceae family. There are about 600 known species for this family. Different species has different size and usually grow along mangrove and in local jungles. The leaves widely in used for craft industries in weaving for different products such as basket and mat. Even the leaves yield strong fibers that applied on different type of handcraft items, like other natural fibers, there are too few number of researchers study on the potential of mengkuang fibers as one of the alternatives for natural fiber to fabricate FRP plate. Only a little number of journals provide information regarding to mechanical properties of mengkuang fiber. Thus, further study should be carried out to investigate the methods to improve the mengkuang fiber properties and mechanical properties of mengkuang fiber composite plate.

1.3 RESEARCH OBJECTIVES

The main aim of this research project is to study the potential use of mengkuang leaves as one of the alternative for natural fiber to assemble as mengkuang leaves-epoxy composite plate (MLECP) for strengthening and retrofitting of reinforced concrete structures. The following are the objectives to be achieved in this study:

i. To identify the behavior of the mengkuang leaves before and after chemical treatment.
ii. To evaluate the performance of MLECP in longitudinal direction with epoxy resin in the form of different fiber-to-volume ratio.
iii. To study the structural behavior of reinforced concrete beams strengthened with MLECP at the flexural zone in terms of load deflection behavior, crack pattern and failure mode.

1.4 SCOPE OF RESEARCH

Mengkuang leaves used in this study are grown locally in Malaysia. The leaves obtained is processed and cut into strips. Mengkuang leaves were treated using alkali solution with different concentration. The preferred alkali solution is sodium hydroxide (NaOH) with 2%, 5% and 8% and the untreated and treated mengkuang leaves was sent

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