UNIVERSITI TEKNOLOGI MARA

SHEAR AND FLEXURAL BEHAVIOUR OF REINFORCED CONCRETE BEAM EXTERNALLY STRENGTHENED WITH FIBER REINFORCED POLYMER (FRP)

SYED HAZNI ABD GANI

Thesis submitted in fulfillment
of the requirements for the degree of
Master of Civil Engineering

Faculty of Civil Engineering

December 2016

ABSTRACT

The utilisation and application of natural fiber based Fibre Reinforced Polymer (FRP) as strengthening material is still rare. In addition, the repairing and strengthening method needs improvement to enhance the performance of structural strengthening. The potential of natural fibers based FRP as strengthening materials was explored in the present study and its performance was compared with those of synthetic based FRP. The performance was measured in terms of shear and flexural strength of strengthened reinforced concrete (RC) beam with respect to various of shear span distance and length of FRP plates and bars. Carbon Fiber Reinforced Polymer (CFRP), Glass Fiber Reinforced Polymer (GFRP) and Kenaf Fiber Reinforced Polymer (KenFRP) were used as strengthening materials. Two (2) techniques of strengthening namely External Bonded Plate (EBP) and Near Surface Mounted (NSM) were adopted. For EBP method, twenty four (24) RC beam specimens with the size 250 mm x 400 mm x 3000 mm were fabricated. It was a flexural strengthening but tested in shear with FRP plate size of 100 mm x 1.2 mm x 2700 mm that was glued on the tension surface of the beam specimens. Two (2) variables were investigated which are types of FRP and various shear span distance which are 300 mm, 220 mm and 100 mm. For the NSM method, twenty (20) RC beams with the size same as these strengthened with EBP method were fabricated. The beam specimens flexural strengthened with 8 mm diameter of bar and the bar was glued at groove of the beam soffit. Two (2) variables were investigated between type of FRPs and various length of FRP bar which are 1250 mm, 1750 mm and 2500 mm length. The four point bending test was adopted. The load-deflection curve was distinguished in order to determine the behaviour both of the beam specimens strengthened using two (2) methods namely EBP and NSM. The crack propagation and the effectiveness of using various FRP either synthetic or natural fiber corresponding to variables adopted were also assessed. Thus, whether natural fiber based FRP could behave equally good as other synthetic fiber based FRP as strengthening material could be established.

ACKNOWLEDGEMENT

In the name of Allah, the Most Merciful and the Most Compassionate

Firstly, I would like to express my utmost gratitude to Allah the Mighty, who gives me the opportunity to pursue Master Degree in Civil Engineering and also give the strength and ability to complete this thesis.

Million of gratitude goes to my supervisor, Prof. Dr. Azmi bin Ibrahim, for all his guidance, assistance, suggestion, opinion, support, understanding through the whole progress to fulfill the requirements of this thesis. Deepest appreciation also goes to co. supervisor Prof. Dr. Hamidah binti Mohd Saman and Prof. Ir. Dr. Zuhairi bin Abd Hamid, Executive Director of Construction Research Institute of Malaysia (CREAM) on their co-operation, help, support, guidance, suggestion and opinion in ensuring a work progress. I would also like to express sincere gratitude to the laboratory personnel namely; Mr Azizi bin Arshad and Mr. Mohd Faizal Mohd Yusof for their help in casting the specimens and conducted the testing's.

Finally, I would like to thank my beloved parents and family for their everlasting support and encouragement. Lastly, I would like to express my special 'thank you' to all my fellow friends for their valuable support. Without the co-operation, guidance and help from concerned parties or individuals, this thesis would not be completed. Your help is highly appreciated.

TABLE OF CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 RESEARCH BACKGROUND

In the past few decades, fiber reinforced polymer (FRP), especially synthetic fiber based FRP, has been widely used as a repairing, retrofitting and strengthening material either in the form of sheet, plate or bar. Previous studies (Lorenzis and Nanni, 2002; El-Hacha *et al.,* 2004; Achintha and Burgoyne, 2006; Jumaat *et al.,* 2006; Islam, 2010; Hollaway, 2010; Vinodkumar and Muthukannan, 2014; Sen and Reddy, 2014; Spadea *et al.,* 2015) have proven the ability of FRP to upgrade the structural integrity of deteriorated reinforced concrete structures.

Fiber reinforced polymer (FRP) has been explored due to its advantages such as being lightweight, easy to install and non-corrodible material (Arya *et al.*, 2002; El-Hacha and Rizkalla, 2004; Hollaway, 2010; Sen and Reddy, 2014; Spadea *et al.,* 2015). In addition, increasing the depth cover thickness of the reinforced concrete (RC) members is the way to increase the lifespan of structures due to concrete deterioration as a result of reinforcement corrosion and surface cracks.

However, deep cover will increase the risk of concrete surface to crack. As a result, concrete spalling and cracks will occur and the height or space of area will be reduced due to increase in cover. Therefore, the introduction of Externally Bonded Plate (EBP) or Near Surface Mounted (NSM) method as the structural strengthening alternative methods apart from the application of deep cover in reinforced concrete structures is becoming more feasible.

At present, business in structural strengthening of RC structures is slowly penetrating the construction sector in Malaysia. This can lead to a better understanding of the matter and prove the advantages of performance based application as strengthening materials. However, due to the lack of support from the construction industry and also the absence of guideline or standard in the country, it has hindered the implementation of the strengthening work using FRP.