BEHAVIOUR OF GLASS FIBER REINFORCED POLYMER CONCRETE BEAMS STRENGTHENED WITH CARBON FIBER REINFORCED POLYMER PLATE

NORHAFIZAH BINTI SALLEH

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Civil Engineering)

School of Civil Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

FEBRUARY 2021

DEDICATION

This thesis is dedicated to my family and my collages, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

ACKNOWLEDGEMENT

In preparing this thesis, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main thesis supervisor, Prof Madya Dr Abdul Rahman bin Mohd Sam, for encouragement, guidance, critics and friendship. I am also very thankful to my co-supervisor Prof Madya Dr Jamaludin bin Mohamad Yatim for their guidance, advices and motivation. Without their continued support and interest, this thesis would not have been the same as presented here.

I am also indebted to Universiti Tun Hussein Onn Malaysia (UTHM) for funding my PhD study. Librarians at UTM also deserve special thanks for their assistance in supplying the relevant literatures.

My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family member.

ABSTRACT

The use of fiber-reinforced polymer (FRP) bars in reinforced concrete (RC) structures has emerged as an alternative to traditional RC due to the corrosion of steel in aggressive environments. FRP materials are non-corrosive, non-conductive, lightweight and possess high longitudinal tensile strength, which are advantageous for their use in civil infrastructure. Among the many of FRP available, Glass Fibre Reinforced Polymer (GFRP) appears to be the most affordable compared to other FRP such as Carbon Fibre Reinforced Polymer (CFRP) and Aramid Fibre Reinforced Polymer (AFRP). However, it has been reported that concrete beam reinforced with longitudinal GFRP reinforcement exhibit large deflection due to low modulus of elasticity of the GFRP bars. There is still lack of information on repairing or strengthening of GFRP reinforced concrete beams problem due to larger deflection compared to conventional reinforced concrete beam. In addition, only limited studies numbers reported the contribution of strengthening method in preventing large deformation of GFRP reinforced concrete beams. Most of previous studies were focusing on the use of ordinary reinforced concrete beams (with steel bars) strengthened with CFRP plates. Strengthened concrete beams reinforced with conventional steel reinforcement behave differently than beams reinforced with GFRP reinforcement, in such that the steel reinforcement usually yield before GFRP rupture. Thus, in this study the investigation on the behaviour and performance of GFRP reinforced concrete beam strengthened with CFRP plate was carried out. The effects of the specific properties and characteristics of CFRP plate on the performance of the beams was also studied. In addition, the development of analytical modelling was conducted to predict the optimum CFRP plate bond length and Nominal Moment Capacity in strengthening of GFRP reinforced concrete beams. The study comprised of experimental work, analytical investigation and numerical modelling. This study involved two design conditions of in total ten reinforced concrete beams which is over reinforced design (OR) and under reinforced design (UR). Two reinforced concrete beams reinforced with steel bar (control beam), two reinforced concrete beams with GFRP reinforcement and six GFRP reinforced concrete beams strengthened with different bond length of CFRP plate were tested. Analytical study using Finite Element Analysis (FEA) was used to simulate and verified the experimental data and parametric study. This parametric study was involved the variation of geometrical of CFRP plate in different length. The results from the test show that beam reinforced with GFRP bar resulted in higher flexural load in both conditions of design OR and UR compared to steel reinforced concrete beam with increasing of flexural load by 31.8% to 47.17%, respectively. However, GFRP reinforced concrete beams exhibit greater deflection due to its low modulus of elasticity compared to steel reinforced concrete beams. GFRP reinforced concrete beam strengthened with CFRP plate recorded a good performance in terms of ultimate load and deflection although having a CFRP plate bond length ratio between 0.53 up to 0.96. Result from Finite Element Analysis also showed the same trend behaviour of GFRP reinforced concrete beams strengthened with CFRP plate with experimental results. Results from parametric study obtained the optimum CFRP plate bond length ratio for GFRP reinforced concrete beams strengthened with CFRP plate is 0.83. Additionally, the new equation predicted the Nominal Moment Capacity of GFRP reinforced concrete beam strengthened with CFRP plate well. Using the developed equation, the predicted results were in good agreement in predicting the nominal strength of strengthened beams with mean ratio of the test results to predicted results about 1.07

ABSTRAK

Penggunaan bar polimer bertetulang gentian (FRP) dalam Struktur Konkrit Bertetulang (RC) telah muncul sebagai alternatif kepada rasuk konkrit tradisional disebabkan oleh pengaratan keluli di kawasan persekitaran yang agresif. Bahan FRP tidak karat, bukan bahan pengalir, ringan dan mempunyai kekuatan tegangan yang tinggi yang sangat diperlukan untuk kegunaan dalam pembinaan infrastruktur. Di antara FRP yang terdapat dipasaran, polimer bertetulang gentian kaca (GFRP) adalah yang paling sesuai berbanding dengan FRP lain seperti polimer bertetulang gentian karbon (CFRP) dan polimer bertetulang gentian aramid (AFRP). Walau bagaimanapun, telah dilaporkan bahawa rasuk konkrit bertetulang GFRP bar akan mengalami lenturan besar disebabkan oleh modulus keanjalan yang rendah. Pada masa kini masih terdapat kekurangan maklumat mengenai pembaikan atau pengukuhan masalah rasuk konkrit bertetulang GFRP oleh kerana lenturan yang lebih besar berbanding dengan rasuk konkrit konvensional. Disamping itu, hanya sebilangan kecil kajian yang melaporkan sumbangan kaedah pengukuhan dalam mencegah ubah bentuk yang besar rasuk konkrit bertetulang GFRP. Kebanyakan kajian terdahulu telah memberi tumpuan kepada penggunaan rasuk konkrit bertetulang biasa (dengan bar keluli) diperkukuhkan dengan plat CFRP. Pengukuhan rasuk konkrit bertetulang keluli menggunakan plat CFRP adalah berbeza dengan rasuk konkrit bertetulang GFRP. Ini kerana tetulang keluli akan mengalami kemuluran dahalu sebelum plat GFRP putus. Oleh itu, dalam kajian ini siasatan ke atas tingkah laku dan prestasi rasuk konkrit bertetulang GFRP yang diperkukuhkan dengan plat CFRP telah dijalankan. Kesan, sifat khusus dan ciri-ciri daripada CFRP plat kepada prestasi rasuk juga telah dikaji. Di samping itu, pembangunan pemodelan analisis unsur terhingga telah dijalankan untuk meramalkan panjang optimum lekatan plat CFRP dan kapasiti nominal momen dalam pengukuhan rasuk konkrit GFRP. Kajian ini terdiri daripada kerja eksperimen, penyiasatan analitikal dan pemodelan berangka. Kajian ini melibatkan dua jenis rekabentuk iaitu sejumlah 10 rasuk konkrit bertetulang yang bertetulang lebih (OR) dan bertetulang kurang (UR). Dua rasuk RC ditetulangkan dengan bar keluli (rasuk kawalan), dua rasuk konkrit mengunakan tetulang GFRP dan enam rasuk konkrit bertetulang GFRP yang diperkukuhkan dengan panjang lekatan plat CFRP yang berbeza telah diuji. Analisis analitikal menggunakan analisis unsur terhingga telah digunakan bagi mensimulasikan dan dianalisa pada rasuk yang diuji dan kajian parametrik. Kajian parametrik ini melibatkan variasi geometri plat CFRP dengan panjang lekatan yang berbeza. Hasil kajian ini menunjukkan bahawa rasuk bertetulang GFRP menyebabkan lenturan yang lebih tinggi dalam kedua-dua kategori rasuk konkrit bertetulang lebih (OR) dan bertetulang kurang (UR) berbanding dengan rasuk konkrit keluli dengan peningkatan beban lentur masing-masing sebanyak 31.8% kepada 47.17%. Walau bagaimanapun, lenturan yang besar dalam rasuk konkrit bertetulang GFRP adalah disebabkan oleh modulus keanjalan yang rendah berbanding rasuk keluli. Rasuk konkrit bertetulang GFRP yang diperkukuhkan dengan plat CFRP mencatatkan prestasi yang baik dari segi beban muktamad dan pesongan walaupun mempunyai nisbah panjang lekatan plat CFRP 0.53 sehingga 0.96 sahaja. Berdasarkan keputusan analisis berangka, didapati ketepatan yang munasabah dari segi beban lentur dengan data dari keputusan kerja makmal. Keputusan kajian parametrik menunjukkan nisbah panjang lekatan yang optimum bagi plat CFRP pada rasuk konkrit bertetulang GFRP adalah 0.83. Tambahan pula, formula kekuatan nominal rasuk yang direka memenuhi ketetapan nilai bagi rasuk konkrit bertetulang GFRP yang dikukuhkan mengunakan plat CFRP dengan ketepatan 1.07.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACI	-	American Concrete Institute Committee
APC	-	Advanced Polymer Composites
ATENA	-	Finite Element Software
BR	-	Bar Rupture
BSI	-	British Standard Institution
CFRP	-	Carbon Fiber Reinforce Polymer
CR	-	Concrete crushing
FEA	-	Finite Element analysis
FR-	-	Flexural Failure
FRP	-	Fiber Reinforced Polymer
GFRP	-	Glass Fiber Reinforced Polymer
GFRP + CFRP	-	GFRP reinforced concrete beam strengthened with CFRP plate
HFRP	-	Hybrid Fiber Reinforced Polymer
HM	-	high modulus
HSC	-	High strength concrete
HT	-	high tenacity
IC	-	Interfacial Concrete
IM	-	intermediate modulus
OR	-	Over reinforced
PED	-	Plate End Debonding
RC	-	Reinforced Concrete
RCB	-	Reinforced Concrete Beam
UHM	-	ultra-high modulus
UR	-	Under reinforced
UTM	-	Universiti of Technologi Malaysia

LIST OF SYMBOLS

ρ_f	-	Reinforcement Ratio
L_p/L_n	-	Bond Length Ratio Of CFRP Plate
b	-	Width
h	-	Height
ρ_{fb}	-	Balanced Reinforcement Ratio
A_f	-	Area Of FRP Tensile Reinforcement
f'_c	-	Design Characteristic Concrete Compressive Strength
f_{fu}	-	Tensile Strength of The FRP Reinforcemen
β_1	-	Stress Block Parameter
M_n	-	Nominal Bending Resistance
d	-	Effective Depth
ε_{fu}	-	FRP Rupture Strain
ε_{cu}	-	Concrete Crushing Strain
f_f	-	Stress In The FRP Reinforcement In Tension
cb	-	Distance From Extreme Compression Fibre To Neutral Axis
$\emptyset$	-	Strength Reduction Factor
Mu	-	Ultimate Moment
a_v	-	Shear Span

LIST OF APPENDICES

CHAPTER 1

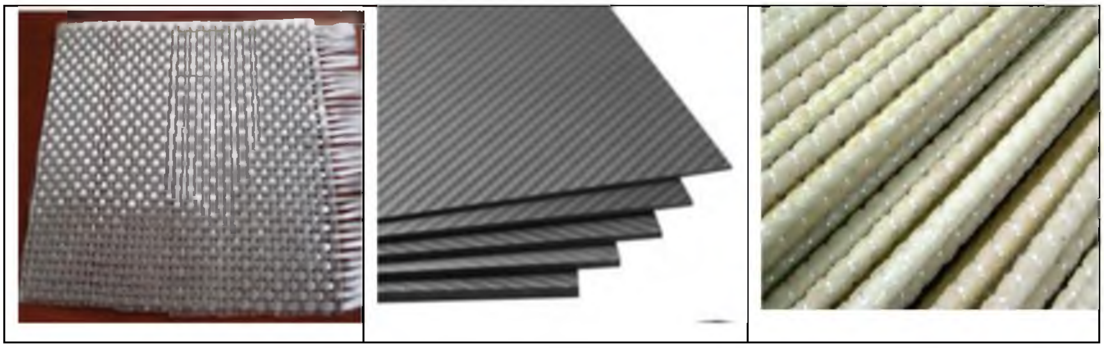
INTRODUCTION

1.1 Introduction

Advanced Polymer Composites (APC) materials or known as Fiber Reinforced Polymer (FRP) represent one of the most promising new reinforcing materials used in construction industries. At first, the applications of FRP are predominantly in the aerospace and the off-shore industries. However, in the last four decades the potential advantage of FRP as an alternative building materials has commenced in civil and structural engineering. In the 1970s, the use of FRP had been accepted for the construction of building since this material had been fully made from polymer composites. As an examples of the use of FRP are in the construction of tower of BBVA headquarters in Madrid (Miguel and Diaz, 2015), constructed a highway bridge with decks using an FRP-SIP formwork and FRP grillage reinforcement at Wisconsin (Wan, 2014).

Deterioration of reinforced concrete structure due to corrosion of reinforcement or continual upgrading of the structure such as increase of traffic load on bridges has resulted in a large number of structures require repairing and strengthening. To remedy this problem, especially in bridges, building and marine structures, various measures and techniques have been used such as increased concrete cover thickness, the use of cathodic protection, and use of different types of reinforcement such epoxy coated steel bars and stainless steel. Mainly due to corrosion problem found in steel bar of reinforced concrete (RC), engineers started to introduce FRP bar as a substitute to this conventional reinforcement material. Steel reinforcement embedded in concrete structure protected by high alkalinity of the concrete (pH >10) and surrounded by concrete cover against corrosive agent such as chloride ion (CI), moisture (H_2O) and oxygen (O_2). However, the durability of concrete is normally limited depending on the surrounding enviroment. Moreover, the concrete is always exposed to an aggressive environment that lead to carbonation process causing reduction of concrete alkalinity which resulting in corrosion of steel reinforcement. Some previous studies pointed out the corroded reinforcement significantly affects the strength capacities and performance of RC beams (Rodriguez, Ortega and Casal, 1997; Almusallam, 2001; Abosrra, Ashour and Youseffi, 2011). Therefore, high maintenance cost of repair work for rehabilitation or steel reinforcement replacement is indispensable to overcome corrosion problem.

FRP are made of inorganic high strength fibres, such as carbon, glass or aramid which are impregnated with a resin matrix. The result indicates unique physical and mechanical properties of FRP. Nonetheless, its properties depend on the combination properties of fibres and resin, as well as fraction of the fibres and resin (Alberto, 2013; Correia, 2015). In comparison with steel reinforcement properties, the FRP reinforcement offer an outstanding performance. Johnson (2009) stated that FRP has strength to weight ratio 10 to 15 times more than steel. Another advantage of FRP is that is non-magnetic and provides excellent corrosion resistance which can lead to lower life cycle cost. As lightweight reinforcement material, FRP is easier in fabrication, transportation, installation and handling, even inaccessible or restricted working are compared to the steel. Commercially, there are three different types of FRP, made of glass, aramid, and carbon for application as reinforcement for non-structural or structural members. FRP has numerous types and shape such as rods, sheets, plates and grid as shown in Figure 1.1. In the construction industries, the application of FRP are not limited only to the reinforcement of concrete but also in rehabilitation of structure such as in beam and column strengthening.



(a) (b) (c)

Figure 1.1 Various Types and Shapes of FRP (a) sheet (b) Plate (c) Rod (FIB Bulletin 14, 2001).

Among various types of FRP, glass fibre reinforced polymer (GFRP) is mostly used commercially as the reinforcement materials. The use of GFRP reinforcement has rapidly increased in recent years due to GFRP reinforcement characteristics. One of the most representative example such application in the Pontresina Bridge in Switzerland, in which the superstructure consists of two lateral trusses made of GFRP profiles and a deck also made of GFRP panels (Correia, 2015).

Existing structure may have deteriorated due to environmental factors as with the corrosion of steel reinforcement in superstructure, vehicle collision and design and construction error resulting in lower load capacity than planned. Deteriorated bridges have to be repaired and due to updating design codes, some of the structures may no longer satisfy current requirement especially due to seismic load and the structure needs to be repaired according to current situation. FRP materials have exceptional stiffness and strength to weight ratios and do not required heavy equipment to be installed. Because of this easy handling of FRP plates or sheets has become a popular method for strengthening or retrofitting reinforced concrete bridges and other structures (Bakis *et al*., 2003; Schué, 2004). The epoxy normally used in FRP strengthening can be cured and acts quickly. As it reduces the time that traffic is blocked, FRP strengthening is a very attractive solution. This method widely adopted as solutions for retrofitting existing structures; most applications are related to shear and flexural reinforcement, confinement of columns and joints. National and international code provisions for the design of elements strengthened with FRP Externally Bonded Reinforcements (EBR) are also being issued worldwide FIB

Bulletin 14 (2001); ISIS Canada (2007); ACI 440.2R (2008) and Japan Society of Civil Engineers (2008).

1.2 Problem Statement

Fiber-reinforced Polymer (FRP) materials have been recognized as new innovative materials for concrete reinforcement, rehabilitation and retrofit. Since concrete is poor in tension, a beam without any forms of reinforcement will fail when subjected to a relatively small tensile load. Therefore, the use of FRP to reinforce the concrete is an effective solution to increase the overall strength of the structure. However, when FRP reinforcement ruptures in tension (i.e. tension-controlled failures), there is significant elongation. Extensive cracking and large deflections give warning of impending failure.

Concrete beam reinforced with GFRP reinforcement resulted in higher deflections and larger crack widths compared to steel RC beams with the same reinforcement ratios (Kalpana and Subramanian, 2011). This is because of the low elastic modulus (35-51 GPa) of the GFRP reinforcement, as recognized in the guidelines for the design and construction of structural concrete reinforced with FRP reinforcement in American Concrete Institute Committee (ACI) (ACI 440.1R, 2002). Moreover, GFRP reinforcement show linear-elastic behaviour up to failure without showing any yielding, unlike the behaviour of steel reinforcement (Benmokrane *et al.*, 2000). Likewise, due to the lower stiffness of the GFRP material, GFRP RC beams display lower post cracking bending stiffness than conventional steel reinforced concrete beams (Ascione *et al.*, 2010). Hence, to avoid GFRP rupture, which the failure may occur without warning, ACI 440.1R, (2002) is recommended to design the beams to fail by concrete crushing (over-reinforced). This type of failure is also classified as brittle but is more desirable for GFRP reinforced concrete flexural members (ACI 440.1R, 2002). To overcome the lack of ductility, the margin of safety for the design of GFRP reinforced concrete flexural member is higher than the margin of safety for steel RC flexural members. A strength reduction factor of 0.55 is suggested by ACI 440.1R, (2002) for GFRP rupture to rule the design. In design of over-reinforced GFRP reinforced concrete beams, the strength reduction factor is dependent on the reinforcement ratio and balanced reinforcement ratio. It is well known that beams reinforced with GFRP reinforcement experiences higher load than the beams reinforced with steel bars but have a large deflection due to high strength and low modulus of elasticity GFRP reinforcement (Barris et al., 2009). Hence, to control the deflection rate, higher reinforcement ratio in the tension zone is compulsory for GFRP reinforced concrete beams (Ashour and Habeeb, 2008). Because of the low modulus of GFRP reinforcement, the stiffness of GFRP reinforced concrete beam is relatively low and thus deflection control is an issue.

Carbon Fiber Reinforce Polymer (CFRP) plate is widely used for strengthening of conventional steel flexural member widely reported (Obaidat *et al.*, 2011; Attari *et al.*, 2012; Dong *et al.*, 2013; Baggio *et al.*, 2014). The use of CFRP plate as external strengthening material to GFRP reinforced concrete beam has not been reported in literature. Strengthened concrete beams reinforced with conventional steel reinforcement behave differently than concrete beam reinforced with GFRP reinforcement. As such that the steel reinforcement will exhibit plastic behaviour after yielding point, it is not occurring to the GFRP reinforced concrete beams. This study therefore looks at the behaviour of the flexural behaviour of concrete beams reinforced with GFRP reinforcement and strengthened with CFRP plate. The contribution of the reinforcement and strengthening system on the load carrying capacity of this composite systems was studied.

1.3 Objective of Research

The main aim of this study is to investigate performance of GRFP reinforced concrete beam strengthened with CFRP plate. In order to achieve the aim, the specific objectives of the study are as follows:

(a) To examine the flexural behaviour of reinforced concrete beams with different types of longitudinal reinforcement (steel and GFRP reinforcement) at different longitudinal reinforcement ratios (ρ_f) through experimental work.

(b) To investigate the flexural behaviour of GFRP reinforced concrete beam strengthened with CFRP plate.

(c) To verify the flexural behaviour of GFRP reinforced concrete beam strengthened with CFRP plate by using finite element analysis.

(d) To determine the effective CFRP bond length ratio from experimental and numerical analysis.

(e) To propose an equation for predicting the nominal strength of GFRP reinforced concrete beam strengthened with CFRP plate.

1.4 Scope of Research

This study comprises of large scale experimental work and analytical investigation in predicting the nominal strength behaviour of GFRP reinforced concrete beam strengthened with CFRP plate. The use of glass fibre reinforced polymer (GFRP) to replace conventional steel reinforcement in simply supported rectangular concrete beams was applied. Sand coated and ribbed surface of longitudinal GFRP were selected in order to improve their bond performance. The main parameters investigated in this present study are longitudinal reinforcement ratio (ρ_f), and bond length ratio of CFRP plate (L_p/L_n). The explanation on the specimen details are discussed in Chapter Three.

In order to assess the flexural behavior, the present study focus on beam deformation, cracking and mode of failure of beams. Based on the finding a nominal strength equation is proposed based on experimental and nonlinear finite element results. The present study carried out both experimental, parametric study, analytical investigation and numerical modelling.

Experimental and analytical investigation: Experimental testing was carried out at engineering laboratory. The experimental also work on determination of compressive strength concrete. All beam specimen were cast with high strength concrete and tested after 28 days of curing. Two groups of specimen were prepared and tested under four point-loading systems that were subjected to static load condition. Group 1 and 2 were designed to evaluate the flexural capacities of GFRP reinforced concrete beam with under reinforced and over reinforced design.

All beams have the same sections (width, *b* and height, *h*) except for their CFRP bond length. The effect of CFRP bond length ratio (L_p/L_n) was investigated by three different ratios. The analytical analysis using the Finite Element software known as ATENA was used to simulate and analyse the response of the tested GFRP reinforced concrete beam strengthened with CFRP plate. The software was used to determine the load-deflection performance of GFRP reinforced concrete beam strengthened with CFRP plate with changing of geometrical of CFRP plate.

Numerical Modelling: In this part of the investigation, the analysis from experimental results was evaluated to examine the influence of parameters that affect the flexural performance of GFRP reinforced concrete beam strengthened with CFRP plate. The findings of the analysis between different CFRP bond length ratio and width of CFRP plate were compared. The test results come out with the effective length of CFRP bond length and influence on the flexural strength of GFRP reinforced concrete beam strengthened with CFRP plate. At the end of this study, a new nominal strength design equation to predict the flexural strength capacities of GFRP reinforced concrete beam strengthened with CFRP plate is proposed.

1.5 Significant of Research

The issue of corrosion in the steel reinforcement embedded in reinforced concrete structure has been overcome though the use of new material resulting in low maintenance cost and significant extension of service life of the structure. This condition has been solved by new composite material of non-corrosive FRP which has emerged as an alternative reinforcement material in the construction industries. GFRP has superior durability properties being a non-corrosive material and superior mechanical properties such as high tensile strength and low self-weight. A combination between GFRP and CFRP plate should result in a durable, sustainable and cost effective system. Moreover, externally bonded CFRP is used for strengthening or repairing of existing concrete members to improve load-resistance as well as serviceability. The performance of concrete beam reinforced with GFRP and applicability of different bond length of CFRP plate as strengthening regime for such systems will result in the reduction of the overall cost of CFRP strengthening system. Load carrying capacity of GFRP reinforced concrete beam could be significantly improve with the effective CFRP bond length ratio (Lp/Ln). The proposed nominal strength equation will predict the flexural strength of GFRP reinforced concrete beam strengthened with CFRP plate.

1.6 Layout of Thesis

The thesis comprises of seven chapters which include Introduction, Literature Review, Research Methodology, Experimental and Data Analysis, Finite Element Modelling and Simulation, Nominal Strength Design Equation and Conclusion and Recommendation.

Chapter One, presents an introduction, problem statement, objectives and significant of study.

Chapter Two, presents the literature review of previous studies that discuss about GFRP reinforced concrete beam strengthened with CFRP plate. In this chapter design guidelines and various approaches are identified. This literature review is used as intellectual support and comparison of the present study.

Chapter Three, describes the details of the test specimen preparation, experimental setup, instrumentation and test method involved during experimental work. In addition, this chapter also present the development of numerical simulation procedure by ATENA software.

Chapter four, deals with the experimental result in terms of modes of failure, load carrying capacities, deflection as well as concrete and reinforcement strains for all tested reinforced concrete beams. The results of strain monitoring on concrete, and plate are examined and analyses to determine their relationship with the flexural performance of the GFRP reinforced concrete beam strengthened with CFRP plate.

Chapter Five, presents the development of numerical simulation analysis by the ATENA software with the addition a few parameters considered as parametric study. The numerical simulation predicts and analyses the response of the tested GFRP reinforced concrete beam strengthened with CFRP plate.

Chapter Six, presents the development of flexural strength equation predicting the nominal strength capacities of all tested specimens. All important assumption and key parameters are examined.

Chapter Seven, gives conclusion of the research findings and proposes future work of the present study.

REFERENCES

ACI 440.2R-02, A. (2008) Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures (ACI 440.2R-02), American Concrete Institute.

A. R. Mohd. Sam and S. Abu Hassan (2004) 'Fully Bonded GFRP Composite Footbridge – UTM Experience', in *International Conference on Bridge Engineering and Hydraulic Structures*

ACI 440.1R (2002) *Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures Reported* by ACI Committee 440. American Concrete Institute.

ACI 440.1R (2006) *Guide for the Design and Construction of Structural Concrete Reinforced with FRP Bars*, ACI 440.1R.

ACI 440.1R (2015) *Guide for the Design and Construction of Structural Concrete Reinforced with Firbe-Reinforced Polymer (FRP) Bars* (ACI440.1R-15), American Concrete Institute.

ACI 440.2R (2008) G*uide for the Design and Construction of Externally Bonded FRP Systems, American Concrete Institute ACI* Committee 440.

ACI, A. C. I. (2002) '*Report on High-Strength Concrete* - ACI Committee 363', American Concrete.

Ahmed, E. A., El-Salakawy, E. F. and Benmokrane, B. (2008) 'Bond Stress-Slip Relationship and Development Length of FRP Bars Embedded in Concrete', *HBRC Journal*, 4(3).

Ahmed, S. A. and Safi, A. R. (2008) 'Behavior of RC beams strengthened with CFRP plates using the finite element modeling', pp. 22–24.

Al-Mahmoud, F. *et al.* (2009) 'Strengthening of RC members with near-surface mounted CFRP rods', *Composite Structures*, 91(2), pp. 138–147. doi: 10.1016/j.compstruct.2009.04.040.

Al-tamimi, A. K., Hawileh, R., Abdalla, J., Rasheed, H. A. and Asce, F. (2011) 'Effects of Ratio of CFRP Plate Length to Shear Span and End Anchorage on Flexural Behavior of SCC RC Beams', 08(December), pp. 908–919.

Alagusundaramoorthy, P., Harik, I. E., Asce, M. and Choo, C. C. (2003) 'Flexural Behavior of R Õ C Beams Strengthened with Carbon Fiber Reinforced Polymer Sheets or Fabric', (November), pp. 292–301.

Alberto, M. (2013) 'Introduction of Fibre-Reinforced Polymers − Polymers and Composites: Concepts, Properties and Processes', in *Fiber Reinforced Polymers- The Technology Applied for Concrete Repai*

Almusallam, A. A. (2001) 'Effect of degree of corrosion on the properties of reinforcing steel bars', *Construction and Building Materials*, 15(8), pp. 361–368. doi: 10.1016/S0950-0618(01)00009-5.

Alsayed, S. H. (1998) 'Flexural behaviour of concrete beams reinforced with GFRP bars', Cement and Concrete Composites, 20(1), pp. 1–11.

Altoubat, Junaid, M. T. and Elbana, A. (2020) 'Flexural response of geopolymer and fiber reinforced geopolymer concrete beams reinforced with GFRP bars and strengthened using CFRP sheets', *Structures*, 24, pp. 666–677. doi: 10.1016/j.istruc.2020.02.003.

American Concrete Institute (2015) ACI 440.1R-15: *Guide for the Design and Construction of Structural Concrete Reinforced with FRP Bars*. ACI committee 440.

Ascione, L., Mancusi, G. and Spadea, S. (2010) 'Flexural Behaviour of Concrete Beams Reinforced With GFRP Bars', Strain, 46(5), pp. 460–469.

Ashour, A. F. and Habeeb, M. N. (2008) 'Continuous concrete beams reinforced with CFRP bars', *Proceedings of the Institution of Civil Engineers: Structures and Buildings*, 161(6), pp. 349–357.

Attari, N., Amziane, S. and Chemrouk, M. (2012) 'Flexural strengthening of concrete beams using CFRP, GFRP and hybrid FRP sheets', *Construction and Building Materials*, 37, pp. 746–757.

Babaeidarabad, S., Loreto, G. and Nanni, A. (2014) 'Flexural Strengthening of RC Beams with an Externally Bonded Fabric-Reinforced Cementitious Matrix', *Journal of Composites for Construction*, 18(5), p. 04014009. doi: 10.1061/(asce)cc.1943-5614.0000473.

Baggio, D., Soudki, K. and Noël, M. (2014) 'Strengthening of shear critical RC beams with various FRP systems', *Construction and Building Material*

Bakis, C. E. *et al.* (2003) 'Fiber-Reinforced Polymer Composites for Construction - State-of-the-Art Review', in *Perspectives in Civil Engineering:*

Commemorating the 150th Anniversary of the American Society of Civil Engineers, pp. 369–383. doi: 10.1061/(asce)1090-0268(2002)6:2(73).

Balendran, R. V and Kong, H. (2001) 'A parametric study on the flexural behaviour of plain concrete beams strengthened by externally bonded plates', *Conference on Our World in Concrete & Structures*, 26(100026017), pp. 173–182. Available at: http://cipremier.com/100026017.

Barris, C., Torres, L., Comas, J. and Miàs, C. (2013) 'Cracking and deflections in GFRP RC beams: An experimental study', *Composites Part B: Engineering. Elsevier Ltd*, 55, pp. 580–590.

Barris, C., Torres, L., Turon, a., Baena, M. and Catalan, (2009) 'An experimental study of the flexural behaviour of GFRP RC beams and comparison with prediction models', *Composite Structures. Elsevier Ltd*, 91(3), pp. 286–295.

Benmokrane, B., Zhang, B. and Chennouf, A. (2000) 'Tensile properties and pullout behaviour of AFRP and CFRP rods for grouted anchor applications', *Construction and Building Materials*, 14(3), pp. 157–170.

Bocciarelli, M. *et al.* (2009) 'Fatigue performance of tensile steel members strengthened with CFRP plates', *Composite Structures*, 87(4), pp. 334–343. doi: 10.1016/j.compstruct.2008.02.004.

British Standards Institution (1997) '*Structural use of concrete* BS8110-1:1997', BSI.

British Standards Institution BSI (1983) (1983) '*Testing Concrete (Part 108) Method for Making Test Cubes from Fresh Concrete*'., BS EN 1881:Part 108:1983.

Building Code Requirements for Reinforced Concrete (1962) *ACI Journal Proceedings*, 59(2). doi: 10.14359/7919.

Buyukkaragoz, A. (2010) 'Finite element analysis of the beam strengthened with prefabricated reinforced concrete plate', *Scientific Research and Essays*, 5(6), pp. 533–544.

Cervenka, V. and Cervenka, J. (2015) '*ATENA Program Documentation Part 2-1 User's Manual for ATENA 2D*', p. 154.

Červenka, V., Jendele, L. and Červenka, J. (2012) 'ATENA *Program Documentation Part 1 Theory*', Atena, pp. 1–282.

Chahrour, A. and Soudki, K. (2005) 'Flexural Response of Reinforced Concrete Beams Strengthened with End-Anchored Partially Bonded Carbon Fiber-Reinforced Polymer Strips', *Journal of Composites for Construction*, 9(2), pp. 170–177.

Chin, S. C., Shafiq, N., Nuruddin, M. F. and Farhan, S. A. (2012) 'Strengthening of RC beams with large openings in shear by CFRP laminates', *International Science Index*, pp. 1–6.

Chlosta, M. (2012) 'Feasibility study on fiber reinforcement polymer cylindrical truss bridges for heavy traffic', (July), p. 213.

Choi, Y., Choi, H. and Choi, C. (2011) 'Experimental Study on Behavior of Flexural Member with Lab-Spliced GFRP Bar', 453, pp. 781–784.

Committee, A. C. I. (2002) 'Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures Reported by ACI Committee 440'.

Correia, J. R. (2015) 'Fibre-reinforced polymer (FRP) composites', in *Materials for Construction and Civil Engineering: Science, Processing, and Design*, pp. 501–556. doi: 10.1007/978-3-319-08236-3_11.

David, S. and Rizkalla, S. (2007) 'Flexural Strengthening of Steel Bridges with High Modulus CFRP Strips', *Journal of Bridge Engineering*, 13(2), pp. 192–201. doi: 10.1061/(asce)1084-0702(2008)13:2(192).

Ding, J., Wang, F., Huang, X. and Chen, S. (2014) 'The Effect of CFRP Length on the Failure Mode of Strengthened Concrete Beams', pp. 1705–1726.

Dong, J., Wang, Q. and Guan, Z. (2013) 'Structural behaviour of RC beams with external flexural and flexural-shear strengthening by FRP sheets', *Composites Part B: Engineering*. *Elsevier Ltd*, 44(1), pp. 604–612.

Duthinh, D. and Starnes, M. (2004) 'Strength and Ductility of Concrete Beams Reinforced with Carbon Fiber-Reinforced Polymer Plates and Steel', *Journal of Composites For Construction*, 8, pp. 59–69. doi: 10.1061/(ASCE)1090-0268(2004)8:1(59).

Ebead, U. and Marzouk, H. (2004) 'Fiber-reinforced polymer strengthening of two-way slabs', *ACI Structural Journal*, 101(5), pp. 650–659. doi: 10.14359/13387.

El-nemr, A., Ahmed, E. A., El-safty, A. and Benmokrane, B. (2018) 'Evaluation of the flexural strength and serviceability of concrete beams reinforced with di ff erent types of GFRP bars', *Engineering Structures*. *Elsevier*, 173(June), pp. 606–619.

El-Gamal, S., Abdul Rahman, B. and Benmokrane, B. (2011) 'Deflection behaviour of concrete beams reinforced with different types of GFRP bars', in *Advances in FRP Composites in Civil Engineering - Proceedings of the 5th International*

Conference on FRP Composites in Civil Engineering, CICE 2010, pp. 279–282. doi: 10.1007/978-3-642-17487-2_59.

Emadi, J. and Hashemi, S. H. (2011) 'Flexural study of high strength RC beams strengthened with CFRP plates', *World Academy of Science, Engineering and Technology*, 78, pp. 380–384.

Erki, M. A. and Rizkalla, S. H. (1993) 'A Canadian perspective on R&D, design/codes and technical committees', in *Fiber-Reinforced-Plastic (FRP) Reinforcement for Concrete Structures*, pp. 89–97. doi: 10.1016/b978-0-444-89689-6.50008-2.

Esfahani, M. R., Kianoush, M. R. and Tajari, A. R. (2007) 'Flexural behaviour of reinforced concrete beams strengthened by CFRP sheets', *Engineering Structures*, 29(10), pp. 2428–2444. doi: 10.1016/j.engstruct.2006.12.008.

Faella, C., Martinelli, E. and Nigro, E. (2008) 'Formulation and validation of a theoretical model for intermediate debonding in FRP-strengthened RC beams', *Composites Part B: Engineering*, 39(4), pp. 645–655.

Faherty KF. 'An analysis of a reinforced and a prestressed concrete beam by finite element method. PhD dissertation, University of Iowa, Iowa, USA.(1972).

Fanning, P. J. and Kelly, O. (2001) 'Ultimate Response of RC Beams Strengthened with CFRP Plates', Journal of Composites for Construction, pp. 122–127.

Fathelbab, Ramadan, M. S. and Al-Tantawy, (2011) 'Finite Element Modeling of Strengthened Simple Beams Using Frp Techniques," a Parametric Study', *Concrete Research Letters*, 2(June), pp. 228–240.

Ferreira, A. J. M. *et al.* (2001) 'Modelling of concrete beams reinforced with FRP re-bars', *Composite Structures*, 53(1), pp. 107–116. doi: 10.1016/S0263-8223(00)00182-3.

FIB Bulletin 14 (2001) CEB FIB bulletin 14, Externally bonded FRP reinforcement for RC structures, International Federation for Structural Concrete (fib).

Fico, R. Limit States Design of Concrete with GFRP Bars. University of Naples Federico Ii PHD. (2007)

Fu, D. C., Wen, Y. H. and Wang, B. (2011) 'Experimental Study on Flexural Deformation Behavior of Concrete Beams Reinforced with GFRP Bars', *Advanced Materials Research*, 280, pp. 175–178.

Gemert, V. (2001) 'Concrete Beams Strengthened With Externally', *ACI structural Journal*, (February), pp. 44–56

Ghernouti, Y., Rabehi, B., Benhamna, A. and A, H. M. (2014) 'Strengthening of Concrete Beams by CFRP : Experimental Study and Finite Element Analysis', Strengthening of Concrete Beams by CFRP : Experimental Study and Finite Element Analysis, pp. 47–57.

Goldston, M. W., Remennikov, A. and Sheikh, M. N. (2017) 'Flexural behaviour of GFRP reinforced high strength and ultra high strength concrete beams', *Construction and Building Materials. Elsevier Ltd*, 131, pp. 606–617.

Habeeb, M. N. and Ashour, A. F. (2008) 'Flexural Behavior of Continuous GFRP Reinforced Concrete Beams', *Journal of Composites for Construction*, 12(2), pp. 115–124. doi: 10.1061/(asce)1090-0268(2008)12:2(115).

Hawileh, R. A., Naser, M. Z. and Abdalla, J. A. (2013) 'Finite element simulation of reinforced concrete beams externally strengthened with short-length CFRP plates', *Composites Part B: Engineering. Elsevier Ltd*, 45(1), pp. 1722–1730.

Hill, C. B. (2012) 'Investigation of electrical and impact properties of carbon fiber reinforced polymer matrix composites with carbon nanotube buckypaper layers', *J. Build.Mater. Struct*, 1, pp. 47–57.

Hind, M. K., Özakçab, M. and Ekmekyaparc, T. (2016) 'A Review on Nonlinear Finite Element Analysis of Reinforced Concrete Beams Retrofitted with Fiber Reinforced Polymers', *Journal of Advanced Research in Applied Mechanics*, 22(1), pp. 13–48.

Isis, C. (2007) Reinforcing Concrete Structures with Fibre Reinforced Polymers Reinforcing Concrete Structures with Fibre Reinforced Polymers, *Canada Research Network*.

Jaiswal, M. (2017) 'Experimental Study of Reinforced Concrete (RC) Beams Strengthened by Carbon Fiber Reinforced Polymer (CFRP): Effect of Beam Size and Length of CFRP .', 12(24), pp. 14075–14081.

Japan Society of Civil Engineers (2008) 'Recommendations for Design and Construction of High Performance Fiber Reinforced Cement Composites with Multiple Fine Cracks (HPFRCC)', *Concrete Engineering Series*.

Johnson, D. (2009) *Investigation of Glass Fibre Reinforced Polymer Reinforcing Bars as Internal Reinforcement for Concrete Structures*. *Master's of Applied* Science. University of Toronto.

Junaid, M. T., Elbana, A. and Altoubat, S. (2019) 'Predicting Flexural Capacity of Concrete Beams Reinforced with GFRP Bars and Strengthened with CFRP

Sheets', *Proceedings of the 4th World Congress on Civil, Structural, and Environmental Engineering*, pp. 4–10.

Jung, K. *et al.* (2015) 'Prediction of Flexural Capacity of RC Beams Strengthened in Flexure with FRP Fabric and Cementitious Matrix', *International Journal of Polymer Science*, 2015, pp. 1–11. doi: 10.1155/2015/868541.

Kaklauskas, G., Cervenka, V. and Cervenka, J. (2004) 'Deflection Calculation of RC Beams : Finite Element Software Versus Design Code Methods', in *International Conference on Computing in Civil and Building Engineering-ICCCBE*, pp. 1–8.

Kalpana, V. G. and Subramanian, K. (2011) 'Behavior of concrete beams reinforced with GFRP Bars', *Journal of Reinforced Plastics and Composites*, 30(23), pp. 1915–1922. doi: 10.1177/0731684411431119.

Kang, T. H. K., Howell, J., Kim, S. and Lee, D. J. (2012) 'A State-of-the-Art Review on Debonding Failures of FRP Laminates Externally Adhered to Concrete', *International Journal of Concrete Structures and Materials*, 6(2), pp. 123–134.

Kara, I. F., Ashour, A. F. and Dundar, C. (2013) 'Deflection of concrete structures reinforced with FRP bars', *Composites Part B: Engineering*. *Elsevier Ltd*, 44(1), pp. 375–384.

Khaloo, A. R. and Gharachorlou, A. (2005) 'Numerical Analysis Of Rc Beams Flexurally Strengthened By CFRP Laminates', *Iranin Journal of Civil Engineering*, 3(1), pp. 1–9.

Leung, H. Y. and Balendran, R. V. (2003) 'Flexural behaviour of concrete beams internally reinforced with GFRP rods and steel rebars', *Structural Survey*, 21(4), pp. 146–157.

Li, X. and Zhao, Y. (2009) 'The Non-linear Analysis of Beams Strengthened by Steel Plate', 2009 *International Conference on Computational Intelligence and Natural Computing*. IEEE, (1), pp. 202–205.

Lin, X. and Zhang, Y. X. (2013) 'Bond-slip behaviour of FRP-reinforced concrete beams', *Construction and Building Materials*, 44, pp. 110–117. doi: 10.1016/j.conbuildmat.2013.03.023.

Lin, X. and Zhang, Y. X. (2014) 'Evaluation of bond stress-slip models for FRP reinforcing bars in concrete', *Composite Structures*, 107(1), pp. 131–141. doi: 10.1016/j.compstruct.2013.07.037.

Lotfy, E. M. and Elkamash, W. (2017) 'Open Access Numerical Study of R . C . Beams Strengthening by External Steel Plate, *American Journal of Engineering Research (AJER)*, 6(3), pp. 48–56.

Mahmoud Abdel Hamid. Behaviour of R . C . beams upgraded with externally bonded steel or FRP plates. Loughborough University. (2000)

Masmoudi, A., Ben Ouezdou, M. and Bouaziz, J. (2012) 'New parameter design of GFRP RC beams', *Construction and Building Materials. Elsevier Ltd*, 29, pp. 627–632.

Miguel, J. C. and Diaz, M. A. N. (2015) 'Fiber Reinforced Polymer (FRP): A New Material Used in Façades of Tall Buildings', *CTBUH 2015 New York Conference- Global Interchanges: Resurgence of the Skyscraper City*, pp. 636–644.

Morphy, R. D. (1999) *Behaviour of FRP Stirrups as shear reinforcement for concrete structures*. University of Manitoba.

Mohd Sam and Swamy, (2005) 'Flexural Behaviour Of C Oncrete Beams Reinforced With Glass Fibre Reinforced Polymer Bars', *Jurnal Kejuruteraan Awam*, 17(1), pp. 49–57.

Munjiza, A., Bangash, T. and John, N. W. M. (2004) 'The combined finite-discrete element method for structural failure and collapse', *Engineering Fracture Mechanics*, 71(4–6), pp. 469–483. doi: 10.1016/S0013-7944(03)00044-4.

Nayal, R. and Rasheed, H. A. (2006) 'Tension Stiffening Model for Concrete Beams Reinforced with Steel and FRP Bars', *Journal of Materials in Civil Engineering*, 18(6), pp. 831–841. doi: 10.1061/(asce)0899-1561(2006)18:6(831).

Nor, N. M., Hanif, M., Boestamam, A. and Yusof, M. A. (2013) 'Carbon Fiber Reinforced Polymer (CFRP) as Reinforcement for Concrete Beam', 3(2), pp. 6–10.

Nour, A., Massicotte, B. and Yildiz, E. (2007) 'Finite element modeling of concrete structures reinforced with internal and external fibre-reinforced polymers', *Canadian Journal of Civil Engineering*, 34(3), pp. 340–354. doi: 10.1139/L06-140.

Obaidat, Y. T., Heyden, S. and Dahlblom, (2011) 'Retrofitting of reinforced concrete beams using composite laminates', *Construction and Building Materials*, pp. 591–597. doi: 10.1016/j.conbuildmat.2010.06.082.

Okeil, A. M., Bingol, Y. and Alkhrdaji, T. (2007) 'Analyzing Model Uncertainties for Concrete Beams Flexurally Strenghtened with FRP Laminates', *Proceedings of the Transportation Research Board 86th Annual Meeting*

Ou, J., Wang, B., He, Z., Zhang, X. and Qian, M. (2004) 'Load-deflection response of concrete beams reinforced with FRP bars', *Advances in Structural Engineering*, 7(5), pp. 427–436.

Panahi, M. and Izadinia, M. (2018) 'A Parametric Study on the Flexural Strengthening of Reinforced Concrete Beams with Near Surface Mounted FRP Bars', 4(8), pp. 1917–1929.

Pilakoutas, K. and Waldron, P. (2006) 'Tension Stiffening In Gfrp Reinforced Concrete Beams', in *Measuring, Monitoring and Modeling Concrete Properties*, pp. 711–718. doi: 10.1007/978-1-4020-5104-3_86.

Rafi, M. M., Nadjai, A., Ali, F. and Talamona, D. (2008) 'Aspects of behaviour of CFRP reinforced concrete beams in bending', *Construction and Building Materials*, 22(3), pp. 277–285.

Rahimi, H. and Hutchinson, A. (2001) 'Concrete Beams Strengthened with Externally Bonded FRP Plates', *Journal of Composites for Construction*, 5(1), pp. 44–56. doi: 10.1061/(asce)1090-0268(2001)5:1(44).

Rahman, A., Sam, M. and Swamy, R. N. (2005) 'Flexural Behaviour of Concrete Beams Reinforced with Glass Fibre Reinforced Polymer Bars', Jurnal kejuruteraan awam, 17(1), pp. 49–57.

El Refai, A., Abed, F. and Al-Rahmani, A. (2015) 'Structural performance and serviceability of concrete beams reinforced with hybrid (GFRP and steel) bars', *Construction and Building Materials*. *Elsevier Ltd*, 96, pp. 518–529.

Ritchie, P. A., Thomas, D. A. and Lu, L. W. (1991) 'External reinforcement of concrete beams using fiber reinforced plastics', *ACI Structural Journal*, 88(4), p. 490. doi: 10.14359/2723.

Rodriguez, J., Ortega, L. M. and Casal, J. (1997) 'Load carrying capacity of concrete structures with corroded reinforcement', *Construction and Building Materials*, 11(4), pp. 239–248. doi: 10.1016/S0950-0618(97)00043-3.

Saadatmanesh, H. and Ehsani, M. R. (1991) 'RC Beams Strengthened with GFRP Plates. I: Experimental Study', *Journal of Structural Engineering*, pp. 3417–3433.

Saadatmanesh, H. and Malek, A. M. (1998) 'Design Guidelines for Flexural Strengthening of RC Beams with FRP Plates', *Journal of Composites for Constuction*, 2(4), p. 158.

Sancharoen, P., Kato, Y. and Uomoto, T. (2006) 'Lifecycle repairing cost of rc structure deteriorated by salt attack based on probabilistic model', in Construction and Professional Practices - *Proceedings of the 10th East Asia Pacific Conference on Structural Engineering and Construction*, EASEC 2010.

Sasmal, S., Kalidoss, S. and Srinivas, V. (2013) 'Nonlinear Finite Element Analysis of FRP Strengthened Reinforced Concrete Beams', *Journal of The Institution of Engineers (India)*: Series A, 93(4), pp. 241–249.

Sathishkumar, T. P., Satheeshkumar, S. and Naveen, J. (2014) 'Glass fiber-reinforced polymer composites - A review', *Journal of Reinforced Plastics and Composites*, 33(13), pp. 1258–1275.

Sato Y, Ueda T, S. K. (2002) 'Tension stiffening effect of reinforced concrete member strengthened by carbon fiber sheet', *Proceedings of the international symposium Bond in concrete, Budapest*, pp. 606–613.

Sen, T. and Jagannatha Reddy, H. N. (2013) 'Strengthening of RC beams in flexure using natural jute fibre textile reinforced composite system and its comparative study with CFRP and GFRP strengthening systems', *International Journal of Sustainable Built Environment. The Gulf Organisation for Research and Development*, 2(1), pp. 41–55.

Shier, G. Flexural Behaviour Of Fibre Reinforced Polymer Strengthened Reinforced Concrete Beams At Elevated Temperatures. Queen's University Kingston,Canada. (2013)

Smith, S.and Teng, J.(2002) 'FRP-strengthened RC beams. II: assessment of debonding strength models', *Engineering Structures*, 24(4), pp. 397–417.

Sojobi, A. O., Aladegboye, O. J. and Awolusi, T. F. (2018) 'Green interlocking paving units', *Construction and Building Materials. Elsevier Ltd*, 173, pp. 600–614.

Spadea, G., Bencardino, F. and Swamy, R. N. (1998) 'Structural Behavior of Composite RC Beams with Externally Bonded CFRP', *Journal of Composites for Construction*, 2(3), pp. 132–137.

Supaviriyakit, T., Pornpongsaroj, P. and Pimanmas, A. (2004) 'Finite element analysis of FRP-strengthened RC beams', *Songklanakarin Journal of Science and Technology*, 26(4), pp. 497–507.

Teng, J. G., Chen, J. F., Smith, S. T. and Lam, L. (2002) 'FRP : Strengthened RC Structures', *Polymer International*, 53(2), pp. 232–233. doi: 10.1002/pi.1312.

Teng, J. G., Yao, J. and Engineering, S. (2005) 'Plate End Debonding Failures of Frp - or Steel-Plated Rc Beams : a New Strength Model', *Advances*, pp. 283–290.

Teng, J. G., Yuan, H. and Chen, J. F. (2006) 'FRP-to-concrete interfaces between two adjacent cracks: Theoretical model for debonding failure', *International Journal of Solids and Structures*, 43(18–19), pp. 5750–5778. doi: 10.1016/j.ijsolstr.2005.07.023.

Thamrin, R., Kurniawan, R. and Melinda, A. P. (2017) 'Shear and Flexural Capacity of Reinforced Concrete Members with Circular Cross Section', *Procedia Engineering*, 171, pp. 957–964.

Thomsen, H., Spacone, E., Limkatanyu, S. and Camata, G. (2004) 'Failure Mode Analyses of Reinforced Concrete Beams Strengthened in Flexure with Externally Bonded Fiber-Reinforced Polymers', *Composites*, (April), pp. 123–131.

Toutanji, H., Asce, F., Zhao, L. and Anselm, E. (2006) 'Verifications of Design Equations of Beams Externally Strengthened with FRP Composites', (June), pp. 254–264.

Toutanji, H. and Ortiz, G. (2001) 'The effect of surface preparation on the bond interface between FRP sheets and concrete members', *Composite Structures*.

Ueda, T. *et al.* (2002) 'Study on Behavior in Tension of Reinforced Concrete Members Strengthened by Carbon Fiber Sheet', *Journal of Composites for Construction*, 6(3), pp. 168–174. doi: 10.1061/(asce)1090-0268(2002)6:3(168).

Ueda, T. and Dai, J. (2004) 'New shear bond model for FRP–concrete interface – from modeling to application', in FRP Composites in Civil Engineering - CICE 2004.

Ueda, T. and Dai, J. (2004) 'New shear bond model for FRP–concrete interface – from modeling to application', in *FRP Composites in Civil Engineering - CICE 2004*, pp. 69–81. doi: 10.1201/9780203970850.ch6

Wan, B. (2014) *Using fiber-reinforced polymer (FRP) composites in bridge construction and monitoring their performance: An overview*, *Advanced*

Composites in Bridge Construction and Repair. Woodhead Publishing Limited. doi: 10.1533/9780857097019.1.3.

Yang, D.-S., Park, S.-K. and Neale, K. W. (2009) 'Flexural behaviour of reinforced concrete beams strengthened with prestressed carbon composites', *Composite Structures*. Elsevier Ltd, 88(4), pp. 497–508.

Yuan, H., Teng, J. G., Seracino, R., Wu, Z. S. and Yao, J. (2004) 'Full-range behavior of FRP-to-concrete bonded joints', *Engineering Structures*, 26(5), pp. 553–565.

Zhu, Y. and Zhang, Y. X. (2010) 'Nonlinear finite element analyses of FRP-reinforced concrete slabs using a new layered composite plate element', *Computational Mechanics*, 46(3), pp. 417–430. doi: 10.1007/s00466-010-0485-1.

Zienkiewicz, O. C. and Taylor, R. L. (2000) 'The Finite Element Method Volume 1 : The Basis', *Methods*, 1, p. 708.

.

LIST OF PUBLICATIONS

Journal with Impact Factor

1. **Salleh, N**.,Mohd Sam,.Yatim, J. M., Khalid, N. H. A., Hamid, N. A. A., Jamellodin, Z. and Majid, M. A. (2018) 'Effect of CFRP Plate Length on Flexural Behavior of GFRP Reinforced Concrete Beam Strengthening', Advanced Science Letters, 24(6), pp. 3968–3973. **(IF:1.253)**

Indexed Journal

1. **Salleh, N**., Mohd Sam., Yatim, J. M. and bin Osman, M. F. (2014) 'Flexural behaviour of reinforcd concrete beam with glass fiber reinforced polymer (GFRP) bar strengthened with carbon fiber reinforced polymer (CFRP) plate', in Advanced Materials Research. **(Indexed by SCOPUS)**

2. **Salleh, N**., Mohd Sam, A. R. and Mohd Yatim, J. (2015) 'Flexural Behavior of GFRP RC Beam Strengthened with Carbon Fiber Reinforced Polymer (CFRP) Plate: Cracking Behavior', Applied Mechanics and Materials, 752–753, pp. 610–616. **(Indexed by SCOPUS)**

Indexed Conference Proceedings

1 **Salleh, N**., Abdul Hamid, N. A., Mohd Sam, A. R., Mohd Yatim, J., Thamrin, R., Khalid, N. H. A., Majid, M. A. and Jamellodin, Z. (2017) 'Finite Element Simulation of GFRP Reinforced Concrete Beam Externally Strengthened with CFRP Plates', in MATEC Web of Conferences. **(Indexed by SCOPUS)**