

UNIVERSITI TEKNOLOGI MARA

**FLEXURAL PERFORMANCE OF RC
BEAMS WITH NEAR SURFACE
MOUNTED CFRP PLATE UNDER
TROPICAL CLIMATE EFFECTS**

NAUWAL BINTI HJ SUKI

Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy

Faculty of Civil Engineering

April 2018

ABSTRACT

Environmental factors are one of the reasons for structural deterioration. Deteriorated structures are required to be strengthened and rehabilitated so that it can continue to stand strong throughout its service life. This study focuses on determining the flexural performance of RC beams longitudinally strengthened with CFRP plate using Near Surface Mounted (NSM) method with the effect of tropical climate. Tropical climate parameters such as the air and moisture will recommence the carbonation process. Through carbonation process, the carbon dioxide will gradually penetrates the concrete surface and react with moisture and calcium hydroxide forming calcium carbonate that leads to steel corrosion and weaken the structure. The utilization of CFRP composite materials using NSM method is an alternative to strengthen the structures as it is rust proof and stronger in term of stiffness compared to steel. The flexural performance of RC beams was observed experimentally and analytically. Eleven beam specimens sized 125mm x 300mm x 1800mm (width; height; length) were constructed and placed in both room temperature surrounding and exposed to the tropical climate for 6 and 12 months. The beam were tested under four point static loading once the exposure time has lapsed and finite element model were then developed to validate the experimental works. The results suggested that the concrete, steel, CFRP plate and epoxy adhesive were significantly affected by the environmental agents as the strength continues to decrease over time. Surface roughness and discoloration were also observed on the materials' surfaces with the longer exposure have the most negative influence. Both experimental and computational modelling display an agreement where there is reduction in flexural strength recorded in the strengthened beams exposed to the tropical climate when comparisons were made to its counterparts which are placed indoor. The exposed strengthened beams however display an enhancement in flexural strength compared to the control beam without any strengthening proving that NSM method is able to strengthen the beams even with the effects of the tropical climate.

ACKNOWLEDGEMENT

The highest of gratitude to Allah S.W.T., the creator of all. His blessing and mercy has allowed me to live and serve the world of His.

Special thanks to my beloved husband, my dearest mother, my late father, my family and friends for supporting me towards the end. All of you are the special part that cherished my heart.

I would like to express my sincere gratitude to both my main and co-supervisor, Assoc. Prof. Dr. Mohd Hisbany Mohd Hashim and Assoc. Prof. Dr. Afidah Abu Bakar for guiding me towards the journey of completion. Their knowledge on various things has greatly increased my spirit in completing this study.

I'm deeply indebted to all technicians from Concrete Laboratory, Fabrication Laboratory, Heavy Structure Laboratory and Computer Laboratory who rendered their help during the period of my study.

I humbly extend my thanks to MyBrain15, Ministry of Higher Education for the scholarship, this study would not have been possible without the financial support.

Thank you.

TABLE OF CONTENTS

	Page
CONFIRMATION BY PANEL OF EXAMINERS	ii
AUTHOR'S DECLARATION	iii
ABSTRACT	iv
ACKNOWLEDGEMENT	v
TABLE OF CONTENTS	vi
LIST OF TABLES	x
LIST OF FIGURES	xii
LIST OF PLATES	xv
LIST OF SYMBOLS	xviii
LIST OF ABBREVIATIONS	xix
CHAPTER ONE: INTRODUCTION	
1.1 Background of Study	1
1.2 Problem Statement	2
1.3 Objectives of Study	3
1.4 Scope of Study	3
1.5 Significance of Study	5
1.6 Limitation of Study	5
CHAPTER TWO: LITERATURE REVIEW	
2.1 Introduction	7
2.2 Climate	7
2.2.1 The Occurrence of Day and Night	9
2.2.2 The Four Seasons	9
2.2.3 Climate Classification	10
2.3 Tropical Climate in Malaysia	12
2.3.1 Temperature	12
2.3.2 Humidity	13
2.3.3 Rainfall Distribution	13

2.3.4	Wind	14
2.3.5	Ultraviolet Radiation	14
2.4	Climate Effects on Civil Engineering Built	14
2.5	Fiber Reinforced Polymer (FRP)	16
2.5.1	Glass Fiber Reinforced Polymer (GFRP)	16
2.5.2	Aramid Fiber Reinforced Polymer (AFRP)	16
2.5.3	Carbon Fiber Reinforced Polymer (CFRP)	16
2.5.4	Manufacturing of FRP Composite Materials	17
2.6	FRP Performance under Climate Effects	18
2.7	Near Surface Mounted (NSM)	22
2.8	Concluding Remarks	34
CHAPTER THREE: RESEARCH METHODOLOGY		
3.1	Overview of the Experimental Works and Analytical Program	36
3.2	Beam Specimens and Dimensions	38
3.3	Raw Materials	44
3.3.1	Timber	44
3.3.2	Coarse Aggregates	44
3.3.3	Fine Aggregates	45
3.3.4	Cement	46
3.3.5	Water	47
3.3.6	Steel Reinforcement	47
3.3.7	CFRP Plate	48
3.3.8	Epoxy Adhesive	49
3.4	Mechanical Properties of Materials	50
3.4.1	Sieve Analysis	51
3.4.2	Slump Test	54
3.4.3	Compressive Test	55
3.4.4	Tensile Test of the Steel Reinforcement	56
3.4.5	Tensile Test of the CFRP Plate	58
3.4.6	Tensile Test for the Epoxy Adhesive	60
3.5	Experimental Works	63
3.5.1	Producing Formworks	63
3.5.2	Steel Reinforcement	65