UNIVERSITI TEKNOLOGI MARA

BEHAVIOUR OF CIRCULAR REINFORCED CONCRETE COLUMNS STRENGTHENED WITH IRON-BASED AND NICKEL-TITANIUM SHAPE MEMORY ALLOY (SMA) STRIPS CONFINEMENT

SYAZA NUR IYLIA BINTI ZULKIFLI

Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Civil Engineering)

College of Engineering

August 2023

ABSTRACT

Concrete confinement has been proven to be effective in increasing concrete strength and ductility, where there are mainly two types of lateral confinement methods, namely, passive confinement and active confinement. The application of active confinement in practice is very limited due to practical limitations related to high cost, extensive labour, and excessive hardware requirement in prestressing conventional materials. This research work is proposing other sustainable material as an alternative strengthening material which is Shape Memory Alloy (SMA) material that has been utilized widely in another field. This research aims to investigate the axial behaviour of circular RC columns partially wrapped with Iron-based and Nickel-Titanium Shape Memory Alloy (SMA) materials by experimental work and validation of the results through finite element modelling. The main objectives of this research are to analyse the axial performance of both SMAs strip as the strengthening material to the plain circular RC column. A total of eight (8) concrete cylinder and eight (8) circular RC column specimens were cast and the experimental work is divided into two stages: concrete cylinder and circular RC column confinement. In the first stage of this research, concrete cylinder specimen was tested with both Fe-SMA and NiTi-SMA strip while in second stage of the experimental work, focus is more on to investigate the behaviour of circular RC column under axial loading. Both stages required to evaluate the feasibility and compressive strength enhancement of concrete cylinder and circular RC column with both SMAs strips confinement. The result has been thoroughly discussed includes the axial behaviour, covering the first crack, load carrying capacity, crack pattern and failure modes, load displacement behaviour as well as the stress-strain analysis then the experimental result was validated numerically with simulation by ABAQUS and lastly a fittest model were developed using MATLAB. All experimental SMAs partially confined specimens had managed to achieve the theoretical design load displaying the reliability of the results. Validation of the specimens with FEA models for both SMAs-confined specimens also showed higher stress-strain values than the experimental results with acceptable maximum percentage difference ranged from 9.34 to 14.92% of the ultimate compressive strength. The proposed design model is linearly related to the lateral confining ratio provided by SMAs-confined strips with correlation coefficient of 0.99. The proposed model is optimally achieved and recommended for design use due to its simplicity. SMA is not only a smart material, it also could contribute towards sustainability whereby the SMA able to be utilized in multiple applications, very cost effective and rapid installation. Lastly, the new knowledge on the promising performance of the SMAs material obtained from this research offers an essential contribution towards the construction industry.

ACKNOWLEDGEMENT

First and foremost, praises and thanks to Allah, the Almighty, for His shower of blessings throughout my research work to complete the research successfully.

I would like to express my deep and sincere gratitude to my research supervisor, Dr. Ruqayyah Ismail for giving me the golden opportunity to do the research, providing invaluable guidance and endless support throughout this research. Her patience, motivation, enthusiasm, and immense knowledge have deeply inspired me. A debt of gratitude is also owed to Prof. Madya Ts. Dr. Mohd Hisbany Mohd Hashim as my co-supervisor for his continuous guidance, sincerity and professional advice that enabled me to improve my work. The completion of this research could not have been possible without the expertise of them, my beloved supervisors.

My appreciation is also dedicated to all technical personnel of the Structures and Materials Laboratory, FCE, and Casting Laboratory, FME, for their kind help and assistance in completing the experimental work especially for Mr Muhammad Tarmizi Ismail and Tc. Lesairuamin Leiahs.

I cannot express enough thanks to my parent. They were the first persons that support my decision to further study, 3 years ago. Despite all of the miserable and difficulties that happened to me, they were there for me when no one else was. Thanks Mama and Papa.

To my caring, loving and supportive husband, Nur Asyraf Azam, my special gratitude. Your encouragement when the times got rough are much appreciated and duly noted. It was a great comfort and relief to know you were willing to help and ease countless of problems appeared throughout my study journey. It will never be forgotten.

Finally, this thesis is specially dedicated to my son, Nuh Liyyan. This piece of victory is dedicated to you, my love.

TABLE OF CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 Introduction

Chapter One includes a section on the *Research Backgro*und presented the background literature related to the research problem in *Problem Statement* section. It would be supported with *Research Objectives* to ensure the particular dimensions of the research topic outlined correctly and relevant. Subsequently, this chapter include sections of *Scope*, *Limitation* and *Significance* of the research.

1.2 Research Background

The construction error has continued to puzzle the construction industry for many decades. Concrete structure deterioration and design deficiencies are stated as serious problems that frequently occur in the construction industry. It may lead to the loss of strength, stiffness, durability, and ductility of the existing structure. The safety of the building has been questioned and a threat that also can lead to life-threatening and property damage. Column is the main structural element that carries the vertical loads to the foundation. Failure of a column could lead to the failure of the whole structure, and it is crucial to take immediate action to ensure the safety and stability of the building. The problems have grown and became a serious issue that must be taken into account within the construction industry itself.

To restore or enhance the structural performance to a level required by current design codes, a rehabilitation and strengthening of damaged or deficient reinforced concrete structures has big potentials towards it. From the standpoint of preserving resources such as time, cost, and materials, rehabilitation or strengthening is a more sustainable approach than just demolishing and rebuilding the entire structure. Moreover, the overall carbon footprint of the structure can be preserved and do not require to redesign that will cost a fortune. Thus, an immediate structural strengthening must be highly considered to improve and repair the structure