UNIVERSITI TEKNOLOGI MARA

THE POTENTIAL OF EFFECTIVE MICROORGANISM (EM) INCLUSION IN ENHANCING THE PROPERTIES OF CEMENT PASTE AND CONCRETE

NOORLI BINTI ISMAIL

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

Faculty of Civil Engineering

May 2019

ABSTRACT

Recently, Effective Microorganism (EM) has shown the potential to be used as new additives in cement based materials. Previous research works reported the incorporation of EM increased the compressive and splitting tensile strength of cement based, significantly. However, extensive evaluation of other aspects need to be investigated to study their potential since the incorporation of EM in cement based materials is still new area. Experimental works in this present study showed the incorporation of EM in cement paste increased up to 40% compressive strength and leading to produce low porosity which decreased at least 19% corresponding to cement paste without EM. However, the hydration process was completed longer than specimens without EM due to the earlier reaction of dehydration and decarbonation detected using thermogravimetric (TGA/DTG) test and presence of potassium thulium chloride in EM solution. This can be a reasoning to the delayed initial and final setting time in the microbed cement paste. Furthermore, the high compressive strength and low porosity also leading to improve the internal densification of cement matrix which reported the formation of calcium silicate hydrate (CSH) and ettringite by detecting from formation of bundle shape and needles like pine leaves, acicular, thin, narrow and pointed shape, respectively at later age of 28 days and 60 days using scanning electron microscopy (SEM). The denser and lesser void in internal microstructure for the microbed cement paste also the factor contributes towards high compressive strength. Due to high resulted compressive strength, survivability of EM bacteria in cement paste was successfully detected using Biolog Microbial Identification System (BMIS) by the presence of EM bacteria species *Microbacterium Flavescens*, *Leuconostoc Fallax* and *Achromobacter xylosoxidans* which was able to survive up to 28 days in cement paste. Subsequently, the establishment of relationship between compressive strength and total porosity was established for low, normal and high concrete at the age of 3, 28, 60 and 180 days. Incorporation of EM also produce lower porosity of concrete which was conducted by mercury intrusion porosimetry (MIP). Also the relationship of compressive strength from destructive and non-destructive tests was successfully established. Multivariable linear regression was chosen to predict the compressive strength by applying dual regression equation which considered two (2) independent variables together; pulse velocity and rebound number obtained from the experimental results. The establishment of multivariable regression equation for both specimens was proposed as;

$$\text{Control, } f_c = 0.0245UPV - 0.1572RN - 79.422,\ R^2 = 0.844$$

$$\text{Microbed, } f_c = 0.00247UPV - 0.247RN - 83.803,\ R^2 = 0.915$$

where f_c = compressive strength, UPV = ultrasonic pulse velocity, RN = rebound number

Overall, the incorporation of EM in cement paste and concrete showed the potential to use as new additives in enhancing compressive strength associated with low porosity.

ACKNOWLEDGEMENT

Firstly, I praise Allah, the Almighty for giving me with this opportunity and granting me the capability to complete the thesis. I would like express my sincere gratitude to my main supervisor Professor Dr. Hamidah Binti Mohd. Saman for the continuous support, for her patience, motivation and immense knowledge for completing this long and challenging journey successfully during my tenure as a PhD student. Furthermore, I am also very appreciative to my co-supervisors Associate Professor Dr Noor Hana Binti Hussain for her diligent advice and guidances for the constant help in understanding the multi-discipline area of microbiology. Also to other my co-supervisor Associate Professor Kartini Muhammad. Without their continued support and interest, this thesis would not have been the same as presented here.

I am greatly indebted to Ministry of Higher Education (MOHE) for providing scholarship SLAB, Ministry of Science, Technology and Innovation (MOSTI) for the grant and Universiti Tun Hussein Onn (UTHM), Universiti Teknologi MARA (UiTM) for given me this golden opportunity to pursue PhD, Faculty of Civil and Environmental Engineering (FKAAS), Faculty of Civil Engineering (FCE), Faculty of Applied Science (FCE), Tun Abdul Razak Library (PTAR) and to all technicians and laboratory assistants that have been involved throughout the completion of this thesis.

I wish to acknowledge the support to all my MSc and PhD colleague from FCE and FSG in helping me to understand of the subtle challenge in this journey. Finally, my lovely mother, husband, childrens and dedicated to the loving memory of my very dear late father. I would like to thank you, without your supports, encouragements and understanding, I may unable to go through the PhD journey.

Alhamdulillah.

TABLE OF CONTENT

		Page
CONFIRMATION BY PANEL OF EXAMINERS		**ii**
AUTHOR'S DECLARATION		**iii**
ABSTRACT		**iv**
ACKNOWLEDGEMENT		
TABLE OF CONTENT		**vi**
LIST OF TABLES		**x**
LIST OF FIGURES		**xiv**
LIST OF PLATES		**xxi**
LIST OF SYMBOLS		**xxiv**
LIST OF ABBREVIATIONS		**xxv**
CHAPTER ONE: INTRODUCTION		**1**
1.1	Research Background	1
1.2	Problem Statement	3
1.3	Objectives	5
1.4	Scope of Work and Limitations	6
1.5	Significance of Study	7
CHAPTER TWO: LITERATURE REVIEW		**8**
2.1	Introduction	8
2.2	Bacteria in Effective Microorganism (EM) Liquid	8
	2.2.1 Lactic Acid Bacteria	9
	2.2.2 Photosysnthetic Bacteria	11
	2.2.3 Yeast	13
	2.2.4 Actinomycetes	14
	2.2.5 Fungi	15
2.3	Isolation and Characterisation of Bacteria	15
2.4	Effective Microorganism (EM) Liquid in Cement Based Material	18
	2.4.1 Influence of EM Liquid to Mechanical Properties	18

CHAPTER ONE
INTRODUCTION

1.1 Research Background

Generally, Effective Microorganism (EM) is classified into two types namely EM Non Liquid and EM Liquid. EM Non Liquid is not in liquid form consists of only one pure bacteria species. The bacteria species that have been used in EM Non Liquid for cement based materials is *Bacillus* species (Ramachandran et al., 2001; Dick et al., 2006; De Muynck et al., 2008; Jonkers and Schlangen, 2009; Tittelboom et al., 2010; Arunachalam et al., 2010; Afifudin et al., 2011; Siddique and Kaur, 2011; Navneet, et al., 2012a and Navneet et al., 2012b, Srinivasa et al., 2013; Mondal et al., 2016 and Krishnapriya and Shahinrahman, 2017). The other types of bacteria are *Shawanella* species and *Escherichia Coli* (Ghosh et al., 2003, 2005, 2009 and Siddique and Kaur, 2011). However, EM Non Liquid is not the focus of the present study. Conversely, EM Liquid comes in liquid form consists of more than one bacteria species and widely used in agriculture (Higa, 1991; Szymanski and Petterson, 2003; Lee et al., 2008; Mayer et al., 2008; Karthick et al., 2011; Wolejko et al., 2016 and Kusznierewicz et al., 2017).

Originally, EM Liquid was developed in 1970's at the University of the Ryukyus, Okinawa, Japan by Dr. Teruo Higa, a horticultural Professor (Higa, 1991). The main ingredients of EM are categorised into three or more types of microorganisms namely lactic acid bacteria, photosynthetic bacteria, yeast and actinomyces (Higa, 1999 and Szymanski and Petterson, 2003). These microorganisms are blended with the molasses which is the sugar cane based product resulting from refining process in the factory and it is thick and blackstrap solution. The addition of molasses in EM Liquid as a nutrient medium to EM bacteria in order to promote the bacteria growth. This solution is maintained at a low pH ranges between 3.0 and 4.0 under ambient condition (Lee et al., 2008; Mayer et al., 2010) for the agriculture purposes.

However, study on EM Liquid and its effect towards concrete properties is still new. Only a few studies have been reported (Nobuyuki et al., 2004; Jamaludin et al., 2009; Andrew et al., 2012 and Isa et al., 2016). The preliminary results revealed that