Configuration of Physical and Mechanical Characteristics of Concrete with Calcium Lactate Inclusion

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Abstract: Over the year, the concrete life span has become a major concern in the construction industry, specifically, when concrete structure exposed to aggressive environments. Concrete incorporating with waste material has been widely conducted in order to improve the concrete deterioration. This book is an originally published for the first edition from Universiti Tun Hussein Onn Malaysia. Target audiences for this book are the academics, researchers and students who seek for a deep information on the inclusion of calcium lactate in bio-concrete.

Properties of bio-concrete with the addition of calcium lactate consists of four chapters. The chapters are mostly devoted to highlight the effect of calcium lactate on the mechanical and durability properties of bio-concrete. This finding is a vital topic to ensure the sustainability of concrete structure. Each chapter is presented with tables and graphs to encourage better understanding and visualization in this topic. List of references is attached at the end of each chapter for further information.

We are deeply grateful to all the reviewers for their time and constructive comments.

Keywords: Physical, concrete, durability, structure

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PREFACE

Over the year, the concrete life span has become a major concern in the construction industry, specifically, when concrete structure exposed to aggressive environments. Concrete incorporating with waste material has been widely conducted in order to improve the concrete deterioration. This book is an originally published for the first edition from Universiti Tun Hussein Onn Malaysia. Target audiences for this book are the academics, researchers and students who seek for a deep information on the inclusion of calcium lactate in bio-concrete.

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With best wishes.

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Introduction to Concrete

1.1 Background of concrete

Concrete is the most widely used construction material in the globe. It is also the most preferred construction material for a wide range of buildings, bridges, and other civil engineering structures. It gains its popularity due to the ease of being cast into various shaped and sizes and being cheaper compared to other building materials. The main strength of concrete lies in its compressive strength which is higher than conventional building materials such as bricks and stone masonry. The development of concrete technology had triggered various types of concrete namely, foam concrete, light-weight concrete, high strength concrete and Self-compacting concrete (SCC). Foam concrete is a lightweight concrete that is made of Portland cement paste or cement filler matrix (mortar) with a uniformly distributed pore structure produced by adding a forming agent. The purpose of this type of concrete was to increase lightness and strength. Self-compacting concrete (SCC) was designed to ease the concrete casting in areas where it is hard to reach small. Self-compacting concrete is quite suitable to be used in structural elements with dense reinforcement. SCC does not normally require many people to work on and can set in a free short period accelerating the speed of construction. Apart from self-compacting concrete (SCC), a non-combustible and non-flammable concrete is Geo-polymer concrete. Geo-polymer concrete utilizes the waste material from industries such as fly ash, silica fume, biomass

1.2 Conclusion

It can be concluded that the durability of concrete has become a major concern in the construction industry due to the different factors that cause its deterioration. The aggressive chemicals such as chlorides and sulphates greatly affect the concrete durability. In addition, atmospheric conditions, water, and soil also affect the performance of concrete life span. Based on the existing literature, many studies have used different types of concrete to minimize the deterioration of concrete. In the next chapters, bio-concrete containing different types of bacteria will be presented and discussed in great details.

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02

Bio-concrete

2.1 Introduction

Bio-concrete is a combination of biology (micro-organism) and concrete. In 2016, concrete industry was discovered with new technology for improve quality of the concrete. Bio-concrete could be described as application of biological elements inside the concrete. However, it looks slightly industry of concrete favour to use microorganism especially bacteria from specific strain or from extremophilic species to develop bio-concrete. MoeThus, this study focusses on an environmental approach in improving engineering concrete properties and enhancement of self-healing by inducing micro-organisms mainly *Enterococcus faecalis and Bacillus sp*.

Ramachandran et al., 2001 stated the bacterial concrete refers to a new type of concrete in which selective cementation of porous media by microbiologically induced $CaCO_3$ has been introduced for remediation of damaged structural formation or micro cracks.

The field of using bacterial to improve concrete appears to be more beneficial as bacterial concrete appears to produce more substantially crack plugging minerals than control specimens (without bacteria). Microbial carbonate precipitation (bio-deposition) decreases the permeation properties of concrete. Hence, a deposited layer of calcium carbonate on the surface of concrete resulted in the decrease of water absorption and porosity.

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03

Preparation of Bacteria and Calcium Lactate

3.1 Introduction

This chapter discuss the methods for the preparation of bacteria and calcium lactate. It also discusses the mechanical testing such as compressive, tensile, flexural strength and water penetration.

3.2 Material preparation

Grade 30 concrete mix used is a combination of fine, coarse aggregate, mixed Portland cement, water, bacteria and calcium lactate. Specification of the materials are specified as below:

3.2.1 Fine Aggregate

Fine aggregate is one of the raw materials used in the concrete mixture. The fine aggregate used is accordance to BS 882:1992: Specification for aggregate from natural source for concrete. The Figure 3.1 shows the sand that was used. The sieve analysis results are shown in Figure 3.2. Based on the sieve analysis result, the fine aggregate used conformed to the requirement in BS 882-1992. This stated that fine aggregate used is within the upper and lower limit boundary which is 150 μm to 5 mm.

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04

Testing of Bacteria and Calcium Lactate in Concrete

4.1 Introduction

This chapter discusses the results for tests conducted for bacteria (Growth, calculation of amount used and identification of bacteria species), Engineering concrete properties (Compressive strength test, Tensile strength test, Flexural strength test and Water penetration), Microstructure and morphology (SEM and EDX), Chemical composition (XRF) and Self-healing (Stereomicroscope and Ultrasonic Pulse Velocity) of bioconcrete and bioconcrete with added calcium lactate. The overall results are discussed and analyse in detail in this chapter with depiction by using Table, Graphs and Photos.

4.2 Bacteria identification

Bacteria identification was done with several steps as describe in Chapter 3 which were preparation of sample for DNA isolation, DNA quantification by Polymerase chain reaction (PCR), DNA sequence and blasting to NCBI database. The DNA quantification, PCR, DNA sequence and bacteria identification are discussed.

4.7 *Summary*

Based on the overall results, the optimum concentration is 2.18 g/L for both *Enterococcus faecalis* and *Bacillus sp*. The engineering concrete properties results were better with calcium lactate than without. The calcium lactate and bacteria has proven to work efficiently in improving concrete properties. Apart from that, the self-healing of micro-cracks was better with calcium lactate of 2.18 g/L for both *Enterococcus faecalis* and *Bacillus sp*. This is strongly due to calcium lactate crystallizing in concrete which facilitated the self-healing process.

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05

Conclusion and Recommendation

5.1 Isolation and identification of Enterococcus faecalis and Bacillus sp

Sulphate reduction bacteria was isolated from acid mine water, Kota Tinggi, Johor while, *Ureolytic bacteria* was isolated from fresh urine. Both bacteria were enriched to suit the concrete environment. During the enrichment process, the oxygen was removed via purging of pure nitrogen gas and the pH was increased from acidic to alkaline by adding NaOH. After which, the surviving bacteria was innoculated and used in this study. The identification of both bacteria was conducted through DNA sequencing using polymerase chain reaction PCR. Results from PCR was sequence using BLASTX software. From this, the identity of the bacteria was known as *Enterococcus faecalis* for Ureolytic bacteria and *Bacillus sp* for Sulphate reduction bacteria. From the Biosafety Guidelines (2010), both bacterium used are in risk group (RG1). Which stated that microorganism within this group are not harmful to humans and the environment.

5.2 Concrete engineering properties

5.2.1 Compressive strength

Overall, the compressive strength of bioconcrete with the addition of calcium lactate has shown positive results. The best concentration of calcium lactate added into bioconcrete mixture was with 2.18 g/L

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