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Mechanical properties of concrete with *Enterococcus faecalis* and calcium lactate

J.M.Irwan[a,*], L.H.Anneza[a], N.Othman[b], A.Faisal Alshalif[a], M.M.Zamer[a], T.Teddy[a]

[a]*Jamilus Research Centre for Susitainable Const.(JRC), Faculty of Civil and Env. Engineering, University Tun Hussein Onn, Malaysia.*
[b]*Micropollutant Research Centre (MPRC),Faculty of Civil and Environmental Engineering, University Tun Hussein Onn, Malaysia*

Abstract

Concrete is an important material used globally, diverse as it can be applied in all construction type or modify to be apply in specialize construction fields. Adding bacteria in concrete can improve the concrete properties and increase durability due deposited calcite by bacteria. However, calcite deposition by bacteria is limited by calcium available in cement. The objective of this research is to determine the effect of adding calcium lactate as an additional calcium source and bacteria on the concrete properties. The bacteria used is locally isolated and enriched to suite concrete environment. The type of the bacteria used is identified as *Enterococcus faecalis*. The calcium lactate is added into concrete mix with concentrations of 0.001 mol/l, 0.005 mol/l and 0.01 mol/l. Whereas, the bacteria is added as 3% Enterococcus Faecalis. Mechanical properties test such as compressive strength, flexural strength and tensile strength was conducted. Cubes of size 150mm × 150mm × 150mm were prepared for compressive strength test while of Dia 150mm by 300mm cylinder were prepared for tensile strength test. Flexural strength test was performed on prism of size 100mm × 100mm × 500mm. The result of compressive strength shows that adding *Enterococcus faecalis* with 0.005 mol/l of calcium lactate gave the highest strength of 42.8 MPa compared to control of 36 MPa. The tensile strength and flexural strength has a similar trend as compressive strength results.Where, both results were optimum with 0.005 mol/l concentration of calcium lactate . The result of tensile strength shows that *Enterococcus faecalis*with 0.005 mol/l obtained 3.18 MPa compared to control of 2.54 MPa. Flexural strength test result was 6.67 MPa for *Enterococcus faecalis* with 0.005 mol/l compared to control of 4.78 MPa. The overall results of bacteria with added calcium lactate showed promising result and further study on self healing capability is encouraging.

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*Keywords:*Compressive strength; Flexural strength; Tensile strength; Enterococcus faecalis; Calcium lactate

* Corresponding author. Tel.: +60 197758186
*E-mail address:*irwan@uthm.edu.my; theddy_bhagas@yahoo.com

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1. Introduction

Bacteria is a common microorganism found everywhere from soil, lakes, water dams and etc. Siddique and Chahal[1] states that there are approximately 40 million bacterial cells in1g of soil and a million bacterial cells in a millimeter of fresh water. There are approximately five nonillion (5×10^{30}) of bacteria on earth. The bacteria species discovered by scientist from various places all around the world barely scratch the surface as there are constantly new discovery being made. Bacteria are able to promote the precipitation of calcium carbonate in the form of calcite. Calcium carbonate precipitation occurs as a by-product of a common microbial metabolic process which would help produce microbial calcite precipitation [2]. Bacterium added into concrete is able to improve concrete properties by production of calcium carbonate. This has been proven by several researchers done all over the world [1, 2, 3]. However, the bacterium used in this research varies from those used by others. The bacterium identified as *Enterococcusfaecalis* is used in this research, isolated and enriched to suit concrete environment. This process was initiated during the early stage of research by Irwan [4]. The optimum percentage of 3% is used in this research based on previously research trial by Irwan [5]. Based on this trial, it was determine that 3% would provide the optimum results on strength and durability. Determining the optimum concentration of calcium lactate and the effect on compressive strength, flexural strength and tensile strength is the main reason of this research.

2. Experimental program

2.1 Enterococcus faecalis and calcium lactate

Enterococcus faecalis is added into concrete as a partial replacement of water. This bacterium is added into concrete in the form of bacteria liquid culture. One colony of bacteria was added into nutrient broth and shaken for ten days, based on bacteria growth curve. After ten days, the bacteria liquid culture was measured and used in fabrication. The calcium lactate added is measured based on the total amount of water used for fabrication. The calculation can be seen in Table 1. The amount of calcium lactate used in this study is adopted from Xu and Yao [6].

Table 1.Calcium lactate used in fabrication

Chemical formula of calcium lactate	$C_6H_{10}CaO_6$
Molar mass of calcium lactate	218 g/mol
0.001 mol/L × 218 g/mol	0.22 g/L
0.005 mol/L × 218 g/mol	1.09 g/L
0.01 mol/L × 218g/mol	2.18 g/L

2.2 Materials

The bacteria used is isolated from fresh urine and enriched to suit concrete environment. Concrete environment is high in alkaline and near to zero oxygen. All materials used in this study for concrete mixing and the 3% of *Enterococcus faecalis* is based on previously conducted study by Irwan [5]. Whereas, calcium lactate added into fabrication was done in several concentrations, which are 0.001mol/l, 0.005 mol/l and 0.01 mol/l.The amount of material used for every batch casted in fabrication can be seen in Table 2. The calculated amount is based on G30 using DOE method. The fabrication of concrete was done according to BS 1881-125:2013 [7]. The samples were removed after 24 hour and are air dry until tests are conducted.

2.3 Test procedure

Mechanical tests that were performed are compressive strength, tensile strength and flexural strength test. All three tests were conducted using Universal Testing Machine (UTM). All tests were conducted on three samples after 28 days of curing. The average results are reported. Compressive strength test was performed using cubes of size