MECHANICAL PROPERTIES AND SHORT-TERM PERFORMANCE OF SULPHATE RESISTANCE OF EFFECTIVE MICROORGANISMS–FLY ASH GEOPOLYMER CONCRETE

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DEDICATION

In the name of Allah Most Beneficient Most Mercıful

Proclaim! (or Read) in the name of thy Lord and Cherisher, Who created

[Quraan, Al Alaq 96:1]

All glory and honor to Him

This project dedicated to

My wonderful parents who have raised me to be the person I am today

My wife who believe in the richness of learning

My children who made me keen on learning

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Praise Be To Allah S.W.T, the Lord of the World

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ABSTRACT

This project presented an assessment into the mechanical properties and short-term performance of geopolymer concrete prepared using fly ash in addition of Effective Microorganisms (EM) along with alkaline activators when exposed to 5% of Sodium Sulphate for up to 56 days. EM for concrete were being produced locally and used in the construction industry to promote sustainability and green concrete. EM technology was initially formulated to enhance the growth of plants in the agricultural industry and disaster treatment which the process will not produce harmful substances. Previous studies found that EM in Ordinary Portland Cement (OPC) concrete improved the concrete strength and also durability. In this research, the compressive strength of EM-fly ash geopolymer with different EM proportions in the increment of 0% (as control sample), 5%. 10% and 15%, replacing the water content were carried out at 7,14 and 28 curing days to obtain the optimum dosage of EM. Then, the strength obtained was compared to decide the ultimate trial mix before preparing cubes, cylinders and prisms for further assessment purposes. The performance of EM-fly ash geopolymer concrete were compared and discussed to what extent EM-fly ash geopolymer was able to enhance the mechanical properties of concrete. The finding shown that when adding 10% of EM into the fly ash geopolymer concrete, the compressive, density, modulus elasticity, tensile and flexural strength, were slightly contributed to the strength development respectively. Therefore, the study concluded that the optimum percentage of EM added into the fly ash geopolymer concrete was 10% in which enhancing its mechanical properties in a more sustainable, environmental-friendly and obtainable. Furthermore, the presence of EM gave a positive behavior in terms of water absorption and had a better resistant against sulphate attack compared to the fly ash geopolymer with 0% addition of EM at the ages of 14, 28 and 56 days.

ABSTRAK

Projek ini membentangkan penilaian ke atas sifat-sifat mekanikal dan prestasi jangka pendek konkrit geopolimer yang disediakan menggunakan abu terbang dan Mikroorganisma Efektif sebagai bahan tambah bersama dengan pengaktif alkali apabila terdedah kepada 5% Sodium Sulphate sehingga 56 hari. Mikroorganisma Efektif bagi konkrit ini dihasilkan di dalam negara dan digunakan dalam industri pembinaan untuk mempromosikan kelestarian dan konkrit hijau. Teknologi Mikroorganisma Efektif pada awalnya dirumuskan untuk meningkatkan pertumbuhan tumbuhan dalam industri pertanian dan rawatan penyakit yang prosesnya tidak menghasilkan bahan berbahaya. Kajian terdahulu mendapati bahawa Mikroorganisma Efektif dalam konkrit Portland Simen biasa meningkatkan kekuatan konkrit dan juga ketahanan. Dalam kajian ini, kekuatan mampatan Geopolimer abu terbang-Mikroorganisma Efektif dengan perkadaran Mikroorganisma Efektif yang berlainan dalam kenaikan 0% (sebagai sampel kawalan), 5%. 10% dan 15%, menggantikan kandungan air yang dilakukan pada 7,14 dan 28 hari pengawetan untuk mendapatkan dos optimum Mikroorganisma Efektif. Kemudian, kekuatan yang diperoleh dibandingkan dengan menentukan campuran percubaan muktamad sebelum menyiapkan kiub, silinder dan prisma untuk tujuan penilaian selanjutnya. Prestasi konkrit geopolimer abu terbang terbang-Mikroorganisma Efektif dibandingkan dan dibincangkan tentang sejauhmana geopolimer abu terbang-Mikroorganisma Efektif mampu meningkatkan sifat mekanik konkrit. Hasil kajian menunjukkan bahawa apabila menambah 10% Mikroorganisma Efektif ke dalam konkrit geopolimer abu terbang, kekuatan mampatan, ketumpatan, keanjalan modulus, kekuatan tegangan dan lenturan, telah menyumbang kepada peningkatan kekuatan masing-masing. Oleh itu, kajian itu menyimpulkan bahawa peratusan optimum Mikroorganisma Efektif yang ditambah dalam konkrit geopolimer abu terbang adalah 10% di mana boleh meningkatkan sifat-sifat mekaniknya dengan lebih mampan, mesra alam dan mudah diperolehi. Tambahan pula, kehadiran EM memberikan kelakuan positif dari segi penyerapan air dan mempunyai daya tahan yang lebih baik terhadap serangan sulfat berbanding dengan geopolimer abu terbang dengan tambahan 0% Mikroorganisma Efektif pada umur 14, 28 dan 56 hari.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
BS	-	British Standard
EM	-	Effective Microorganisms
CASH	-	Calcium Aluminatesilicate Hydrate
NASH	-	Sodium Aluminatesilicate Hydrate
XRF	-	X-Ray Fluorescence
XRD	-	X-Ray Diffraction
SEM	-	Scanning Electron Microscopy
EDX	-	Energy Dispersive X-Ray
UPV	-	Ultrasonic Pulse Velocity
CO_2	-	Carbon Dioxide
NO_3	-	Nitrate
CH_4	-	Methane
SiO_4	-	Silicate
AlO_4	-	Aluminate
Na_2SiO_3	-	Sodium Silicate
SP	-	Superplasticizer
BA	-	Bamboo Ash
FA	-	Fly Ash
POFA	-	Palm Oil Fuel Ash
RHA	-	Rice Husk Ash
OPC	-	Ordinary Portland Cement
GGBS	-	Ground Granulated Blast Furnace Slag
SCWA	-	Sugar Can Waste Ash
RC	-	Reinforced Concrete
NaCl	-	Sodium Chloride
AAR	-	Alkaline aggregate reactions
H_2SO_4	-	Sulfuric Acid
$MgSO_4$	-	Magnesium Sulphate
NaOH	-	Sodium Hydroxide

LIST OF SYMBOLS

F_c	-	Compressive Strength
F/P	-	Maximum Load
A_c	-	Cross section of the Specimen
ρ	-	Density
M	-	Mass of the Specimen
V	-	Volume of the Specimen
F_{ct}	-	Splitting Tensile Strength
L	-	Length of the Specimen
d	-	Depth of the Specimen
b	-	Width of the Specimen
R	-	Flexural Strength
E_c	-	Modulus Elasticity
ΔL	-	Deformed Length
L_o	-	Initial Length
T	-	Time Taken by the Pulse to Traverse that Length (s)

CHAPTER 1

INTRODUCTION

1.1 Background of the Problem

Concrete has been used for construction since ancient Rome. The era during which concrete was first manufactured depends on how the word ‘concrete’ was defined. Old materials were crude cements created by crushing and burning gypsum or limestone. Lime also refers to calcareous smashed, charred. These became mortar when sand and water were applied to these cements, which was a plaster-like substance used to bind stones to each other. Today, concrete is the single most commonly used structural material in the world and is used in the construction of houses, bridges and mega-structures such as dams, pavements and many more. The reason for this is because the materials used to make concrete are so diverse and readily available; another reason for this is that concrete can be precast or poured into any shape.

Despite the versatility of concrete structures, spalling, corrosion, carbonation are common impairments that sabotage the integrity of structures over time. External events such as earthquake, landslide also impact negatively on our structures. The durability of concrete can be clearly defined as the longevity of materials under different environmental conditions. Concrete is known to be a rock counterpart. It is pretty known long-lasting in the sense that ordinary water or environment does not affect it. These agents can intrude into the concrete matrix, but they do not cause any deleterious effects. Durable life is known to be a period before the material shows signs of distress. This means that the concrete structure has to demonstrate distress. For example, plain concrete is not affected by processes such as carbonation, whereas carbonation corrosion affects reinforced concrete (rc) structures. Some of the most common problems identified are AAR (alkali aggregate reactions), corrosion, sulphate attack, freeze thawing and shrinkage.

Global warming is a worrying issue today and the cement industry also leads to CO_2 emissions. Cement is an essential part of the binding product to be produced concrete in the construction industry. Hence, to produce the cement, not only consume a lot of energy and high temperature about 1500 °C but also emits harmful gas such as CO_2, NO_3 and CH_4 to the atmosphere (Andrew, 2018). About 0.9 ton of cement manufactured releases 1 ton of carbon dioxide being greenhouse gas is mainly responsible for global warming (Sharma et al.,2018). Rapid development in Malaysia has increased the consumption of concrete, where about 16.5 million tons of cement is consumed annually (Bakhtyar et. al, 2017).

As increase the demand of concrete year by year, the demand in high performance and durability concrete also increase. Most of the building like high-rise or bridges needs both strength and durability as important considerations. In construction industries, they focused on ordinary Portland cement (OPC) as the construction material. At the same time, OPC is not effective against aggressive environment condition. Therefore, construction industry was force to produce renewable material that high performance in strength and durability as well as environmental-friendly, such as using fly ash as binder in construction material.

It needs alternative construction materials to reduce carbon emissions and promote sustainable development. One of these is the geopolymer concrete. In addition, it also uses waste materials/by-products and substantial natural resources for the manufacture of geopolymer concrete in order to meet global infrastructure developments. By solving this problem, many researchers are considered to be replacing cement with waste materials. There are two types of waste materials used to replace cement; (i) industrial waste and (ii) agricultural waste; And then these wastes are subdivided into natural and recycled. Some agricultural waste by-products like peanut shell ash, sawdust ash, sugarcane bagasse ash and bamboo ash and so on are now considered for a fully replacement of cement OPC. Therefore, construction industry is force to produce renewable material that high performance in strength and durability as well as environmental friendly.

Recently, the complexity of microorganisms and their often-unpredictable nature and biosynthetic capacities, given a specific set of environmental and cultural conditions, have made it possible for them to be candidates to solve particularly difficult problems in life sciences and other fields. The various ways in which microorganisms have been used over the last 50 years to advance medical technology, human and animal health, food processing, food safety and quality, genetic engineering, environmental protection, agricultural biotechnology and more effective treatment of agricultural and industrial waste are the most remarkable achievements. Many of these technological advances would not have been possible by using common chemical and physical engineering techniques, or, if they had been, would not have been technically or economically feasible.

1.2 Statement of the Problem

Sustainable and green concrete is the only way to get rid of the environmental and sustainability issues mentioned above. The use of green concrete in building, which minimizes the environmental impact and makes it economic-environmental-friendly, may therefore be referred to as sustainable construction. Fly-ash also decreases greenhouse gas emissions and negative effects. As far as the conservation of resources is concerned, geopolymer concrete is a revolutionary building material created by the chemical action of inorganic molecules. Fly ash, a by-product of the coal generated by the thermal power plant, is widely available worldwide. Fly ash is rich in silica and alumina reacts with an alkaline solution formed by an aluminosilicate gel that acts as a binding agent for the concrete. It is an excellent alternative construction material to conventional plain concrete. Geopolymer concrete shall be produced without the use of any quantity of ordinary Portland cement.

However, no previous study regarding the utilization of fly ash in geopolymer concrete with addition of EM is available. Most of the researchers only focuses onto well-known agriculture waste such as sugar cane waste ash (SCWA), rice husk ash (RHA) and palm oil fuel ash (POFA) any many more. This strongly indicates important gaps to be filled in the process of development of an efficient EM-fly ash geopolymer concrete for practical construction purposes. The points to be illustrated in this research are that the application of EM is still at an early stage in the field of construction which is why thorough research is needed to determine the actual effects on concrete. What are the major impacts on the mechanical properties of geopolymer concrete? What is the optimal dosage of EM in geopolymer concrete? To what degree EM would improve the mechanical properties of concrete.

1.3 The Objective of the Study

The aim of this research as mentioned above is to assess on the mechanical properties and short-term performance of sulphate resistance of EM-fly ash geopolymer concrete. The objectives of the research are;

(i) to determine an optimum dosage of EM in fly ash geopolymer concrete;

(ii) to examine the mechanical properties of EM- fly ash geopolymer concrete;

(iii) to evaluate the performance of EM-fly ash geopolymer in enhancing strength and sulphate resistance of EM-fly ash geopolymer concrete.

1.4 Scope of the study

In this experimental work, the trial mix of fly ash geopolymer with different EM proportions in the increment of 0% (as control sample), 5%. 10% and 15%, replacing the water content were developed. The trial mix was carried out first to obtain the optimum dosage of EM at 7, 14, 28 days curing base on compressive strength test. Then, the ultimate design mix consisted of cubes size of 100 x 100 x 100 mm, prisms size of 100 x 100 x 500 mm, and cylinders size of 100 x 200 mm were casted for mechanical properties assessment. For sulphate resistance assessment, cubes strength which immersed in sulphate solution for 14, 28, 56 days were determined based on compressive strength test. The mechanical properties of the EM-fly ash geopolymer concrete such as compressive, density, splitting tensile, flexural, modulus elasticity and water absorption were to be conducted. The materials used and the methods for conducting the tests were given in the following sections.

1.5 Significance of Research

The research study found that the application of EM in geopolymer concrete showed improvements in the various properties of concrete in terms of compressive strength, density, tensile strength, flexural, modulus elasticity, water absorption and sulphate resistance. Since the EM can be generated in the laboratory, it could be shown to be safe. The ultimate design mix of EM-geopolymer concrete will be obtained the optimum dosage of EM to enhance the mechanical properties of concrete. EM-geopolymer exhibited lower rate of water absorption than conventional concrete which was good for concrete durability respectively. It was expected due to the anaerobic and aerobic activities of the microorganism in the pores present in concrete, resulting in a lesser void and therefore less permeability through microstructural changes. The study also found that the use of EM in concrete improves its strength properties and resistance to sulphate attack so that the use of this type of microorganism can create strong and durable structures.

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