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Geo-polymer Bacterial Concrete Using Microorganism

Ramin Andalib[1], Muhd Zaimi Abd Majid[1]*, Mohd Warid Hussin[1], Ali Keyvanfar[1], Amirreza Talaiekhozani[2], Hasrul Haidar Ismail[1]

1- Construction Research Center (CRC), Institute for Smart Infrastructure and Innovation Construction (ISIIC), Faculty of Civil Engineering, Universiti Teknologi Malaysia, UTM Skudai, 81310 Johor Bahru, Malaysia.
2- Department of Civil Engineering, Jami Institute of Technology, Isfahan, Iran.

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Abstract

The existent research investigates the ability of *Bacillus* bacteria species to improve the strength of Geo-polymer concrete based on bio-mineralization mechanism. The appropriate cell concentration of bacteria was introduced in ordinary and Geo-polymer concrete by way of the mixing water to compare their strength and durability. In this research, it was found that the compressive strength growth in Geo-polymer bacterial concrete was the highest in comparison to ordinary bacterial concrete at 90th day. For durability study, the specimens were immersed in 5% H_2SO_4 solution and the result showed that Geo-polymer bacterial concrete had the least weight and strength losses than ordinary bacterial concrete at different ages. This improvement was due to the temperature condition of Geo-polymer bacterial concrete to survive more bacteria for purpose of calcite precipitation. The density and uniformity of concrete were also examined by ultrasonic pulse velocity (UPV) test. The result showed that the density and uniformity of Geo-polymer structural bacterial concrete were more in comparison to other types of concrete.

Keywords: Geo-polymer Bacterial Concrete; *Bacillus* Strain; Concrete Strength and Durability; UPV Test

1 Introduction

Geopolymer, as an inorganic polymer member can be created from Silicon (Si) and Aluminium (AL) of by-product materials [1]. However the polymerization procedure contains a rapid chemical reaction under alkaline situation on Si-AL minerals, the most alkaline activator applied in Geopolymerisation is a combination of sodium silicate and sodium hydroxide [2]. The fundamental difference between ordinary and Geopolymer concrete is the binder which can be obtained from a certain concentration of alkaline activator and Ash mixing.

Palm Oil Fuel Ash (POFA), a waste from Palm oil mill and Fly Ash, a waste from coal-burning power stations which are cheap and available to create Geopolymer concrete. Davidovits was the first, introduced the term of Geopolymer in 1978. The initial research about partially replacement of ordinary Portland cement concrete by Palm Oil Fuel Ash started since 1990 in Malaysia.

Malaysia is focusing on good quality agricultural products such as Palm and it is expected that millions tones of palm oil waste will be produced annually. Hence a lot of money will be spent to transport and maintenance the waste [3]. On the other hand, Fly Ash has been also utilized in replacing Portland cement partially to create Geopolymer concrete. The experiment consequences, demonstrated that high volume Fly Ash Geopolymer concrete is more durable than ordinary cement concrete [4].

This study is an attempt to highlight the use of bacteria in Geopolymer concrete (Palm Oil Fuel Ash mixed with Fly Ash instead of cement) to achieve a sustainable green building material. Geopolymer bacterial concrete is a novel research domain can be used for cementitious materials that cure themselves automatically by bio-mineralization mechanism**.** The concept is to introduce bacteria in concrete, which aids to precipitate calcite in pores and tiny cavity areas.

Bacillus species is an ureolytic bacterium can produce calcite to decrease concrete pores for enhancing the strength and durability. Various *Bacillus* spices of spore-forming bacteria have been used by researchers in their studies: I.e. *Bacillus pasteurii* [5-20], *Bacillus sphaericus [*21-29], *Bacillus cohnii* [30- 32], *Bacillus pseudofirmus* [30- 32], *Bacillus subtilis* [33-36], *Bacillus Megaterium* [37], and *Bacillus alkalinitrilicus* [38]. *Bacillus pasteurii* has been also reclassified as *Sporosarcina pasteurii* [19].This research actually investigates the ability of *Bacillus* bacteria species to improve the strength and durability of Geo-polymer concrete based on calcification and Geopolymerization processes.

Corresponding Author: Muhd Zaimi Abd Majid, Construction Research Center (CRC), Institute for Smart Infrastructure and Innovation Construction (ISIIC), Faculty of Civil Engineering, Universiti Teknologi Malaysia, UTM Skudai, 81310 Johor Bahru, Malaysia, Email: mzaimi@utm.my.

2 Experimental work

2.1 Material

Palm Oil Fuel Ash (POFA), Fly Ash, and Ordinary Portland Cement (OPC), were obtained from Palm oil mill, coal-burning power station, and the local market of Malaysia respectively. The chemical composition of the POFA, Fly Ash, and OPC are shown in Table 1. A combination of Sodium Hydroxide and Sodium Silicate solutions were used to react with the Aluminium and the Silica in the POFA. Fine sand and 10mm aggregates were also used in saturated surface dry condition. The mixtures were designed for the compressive strength of Fcu=25 MPa. The Geo-polymer concrete mix was based on the different ratio of materials to optimize the best mixture. The appropriate components of ordinary and Geopolymer concrete with optimum percentage of Palm Oil Fuel Ash mixed with Fly Ash are shown at Table 2 and Table 3 respectively.

2.2 Microorganism isolation and identification

Soil microorganism isolation is a significant initial stage of many biological researches. In this research, soil samples were taken from Universiti Teknologi Malaysia to isolate bacteria. Soil samples were suspended in 10 ml nutrient broth to place in a water bath with 100ºC temperature for 10 min. Before transferring samples to agar plate serial dilution were done. Subsequently agar plates containing medium culture were incubated at 30 ºC for 24 hours to obtain pure colonies with dilution streaking repetition. In this study, peptone 5.0 g/L, yeast Extract 3.0 g/L, and distilled water were used to create nutrient broth medium culture since peptone 5.0 g/L, yeast Extract 3.0 g/L, agar 12.0 g/L, and distilled water were applied in medium to produce nutrient solid agar. Calcium lactate (80 gram/liter**)** and urea **(**20 gram/liter) as calcium and nitrogen origins were also introduced to medium for bio-mineralization mechanism.

Table1: The chemical composition of the POFA, Fly Ash, and OPC (mass %)

	SiO2	AL2O3	Fe2O3	CaO	MgO	Na2O	K2O	P2O5	LOI
POFA	53.5	1.9	1.1	8.3	4.1	1.3	6.5	2.4	18
Fly Ash	46.7	35.9	5.0	3.92	0.84	0.58	0.5	0.383	1.00
OPC	43.1	5.0	2.6	46.0	1.1	0.2	0.5	0.2	1.3

Table2: Geo-polymer concrete mix with different ratio of ingredients to achieve 25 MPa strength

POFA : Fly Ash	Fly Ash	POFA	Na_2SO_3	NaOH	Sand	Aggregate	water	Plasticizer	Liquid : (PFA+POFA)	Achieved Strength (MPa)
30:70 %	290	123.33	119.05	47.62	530	1233.32	33.33	6.67	0.403	**25.20**
50:50 %	206.67	206.67	119.05	47.62	530	1233.32	33.33	6.67	0.403	20.15
70:30%	123.33	290	119.05	47.62	530	1233.32	33.33	6.67	0.403	15.10
100:0%	0	413.33	119.05	47.62	530	1233.32	33.33	6.67	0.403	12.80

Table3: Appropriate components of Geo-polymer and OPC concrete based on 25 MPa strength

Material	**POFA-Fly Ash (30:70) Geo-polymer Concrete Mass Kg/m^3**	**OPC Concrete Mass Kg/m^3**
Cement	0	429.31
Water	33.33	193.19
10mm Aggregates	1233.32	965.95
Fine Sand	530	792.08
Fly Ash	290	0
POFA	123.33	0
Sodium Hydroxide Solution	47.62	0
Sodium Silicate Solution	119.05	0
Super Plasticizer	6.67	0

Table 4: Colony morphology, cell morphology, Gram stain reaction, and general tests to identify the genus of bacteria

Bacteria Genus	**Colony Morphology (from agar plates)**					**Cell Morphology**	**Gram reaction (+/-)**	**O2 Use**	**Glucose Use**	**Endospore (Y/N)**
	Shape	**Elevation**	**Edge**	**Color**	**Surface**					
Bacillus	circular	flat	entire	cream	smooth	Bacillus-rod	+	aerobe	No gas	Yes

The colony morphology, cell morphology, Gram stain reaction, motility and other general microbiology tests were the significant evidences to identify the bacteria strain. These experiments were included an easy to read table that enables to rapidly identify an unknown isolated bacteria on the basis of Bergey manual of systematic bacteriology (Table4).

2.3 Mix proportioning and test specimens

The appropriate cell concentrations of microorganism ($30*10^5$ cells) were introduced to ordinary and Geo-polymer concrete by way of the mixing water per ml for the current experimental research. The 100 mm x 100 mm x 100 mm cubes were cast and vibrated to compact in a vibration machine and all cubes were cured in ambient conditions at room temperature 26± 4°C after demolding. The compressive strength of the cubes was determined at different ages for different types of concrete. To study the durability of Geo-polymer bacterial concrete against aggressive agents (acidic conditions), the specimens were immersed in a 5% solution of sulfuric acid to compare with other types of concrete at different ages. Ultrasonic pulse velocity (UPV) test was also applied to clearly describe concrete quality in terms of density, uniformity, homogeneity. This is on the basis of the fundamental rule that the velocity of an ultrasonic pulse through any substance place trust in the density of the material.

3 Result and Discussion

The major aim of this research was to survey the microorganism effect on the Geo-polymer concrete strength and durability. Fig.1 (b, c, d, e) demonstrate the compressive strength of different types of concrete without and with appropriate concentration of microorganisms ($30*10^5$) at different ages (14, 28, 45, and 90 days). The maximum strength growth was achieved at 90th day in Geo-polymer concrete. It was found that the addition of microorganism had a positive effect on the compressive strength of Geo-polymer concrete. Fig.2 (a, b) also demonstrate the weight and strength losses of different types of concrete in acidic conditions. The durability study proved that the Geo-polymer bacterial concrete had less weight and strength losses than the other types of concrete in 5% H_2SO_4 solution. Eventually Fig.3 shows the ultrasonic pulse velocity (UPV) test result in different type of concrete. In a comparative manner, higher velocity was achieved since concrete quality was high in terms of density and uniformity.

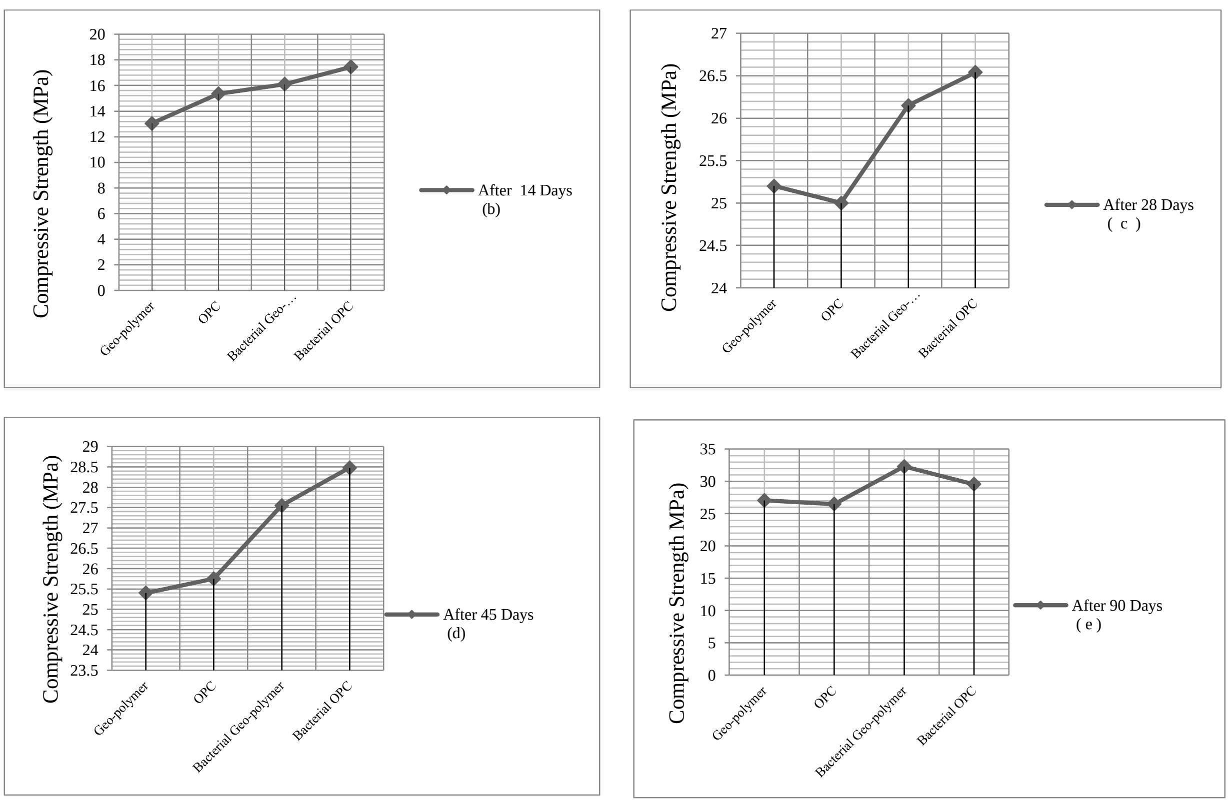

Fig.1 The microorganism effect on the compressive strength of Geo-polymer and OPC concrete without and with appropriate concentration of bacteria

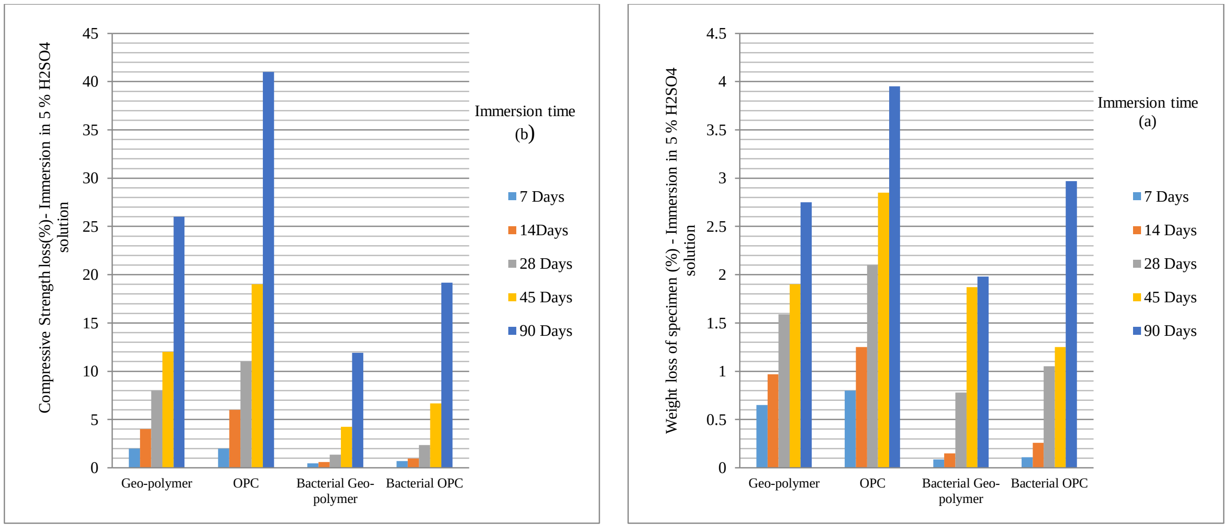

Fig 2: Weight **(a)** and **s**trength **(b)** losses of Geo-polymer and OPC concrete without and with appropriate concentration of bacteria in acidic conditions (Immersion in 5% H_2SO_4)

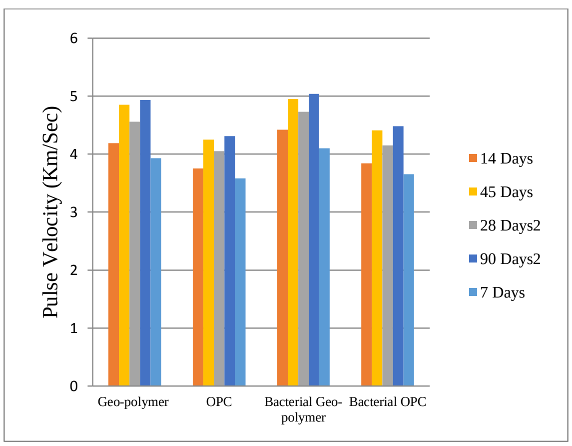

Fig 3: Ultrasonic Pulse Velocity (UPV) test result in Geo-polymer and OPC concrete without and with appropriate concentration of bacteria

4 Conclusions

In this research, we found proof that *Bacillus* bacteria had a favorable outcome on the compressive strength and durability of Geo-polymer concrete. The highest strength growth was obtained in Geo-polymer bacterial concrete with $30* 10^5$ concentration of microorganism. This improvement was due to Geo-polymer concrete temperature conditions to survive more microorganisms to produce more calcite. The durability study also proved with evidence that the Geo-polymer bacterial concrete had less weight and strength losses than the ordinary and Geo-polymer concrete without microorganisms in 5% H_2SO_4 solution. Lastly ultrasonic pulse velocity (UPV) test result verified that the density and uniformity of Geo-polymer bacterial concrete were more than other types of concrete in this research. This improvement was due to filler substance of biology within the concrete pores as a result of microbiologically induced mineral precipitation and Geo-polymer concrete materials component size.

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