PAPER • OPEN ACCESS

Durability of Geopolymer Lightweight Concrete Infilled LECA in Seawater Exposure

To cite this article: R A Razak *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **267** 012012

IOP Conf. Series: Materials Science and Engineering **267** (2017) 012012 doi:10.1088/1757-899X/267/1/012012

Durability of Geopolymer Lightweight Concrete Infilled LECA in Seawater Exposure

R A Razak [1, 2, a)] M M A B Abdullah [1, 2, b)] Z Yahya[1,2, c)] and M S A Hamid[2, d)]

[1] Center of Excellence Geopolymer and Green Technology, School of Materials Engineering, Universiti Malaysia Perlis (UniMAP), 01000, P.O. Box 77, D/A Pejabat Pos Besar, Kangar, Perlis, Malaysia.

[2] Faculty of Engineering Technology, Universiti Malaysia Perlis (UniMAP), Kampus Uniciti Alam, Padang Besar, Perlis, Malaysia.

[a)] Corresponding author: rafizarazak@unimap.edu.my
[b)] mustafa_albakri@unimap.edu.my
[c)] zarinayahya@unimap.edu.my
[d)] sarifhamid4545@gmail.com

Abstract. This paper describes a development of lightweight concrete using lightweight expanded clay aggregate (LECA) in fly ash (FA) based geopolymer immersed in seawater. The objective of this research is to compare the performance of geopolymer concrete (GPC) with ordinary Portland cement (OPC) concrete infilled lightweight expanded clay aggregate (LECA) in seawater exposure. Geopolymer concrete is produced by using alkaline activator to activate the raw material, FA. The highest compressive strength of this study is 42.0 MPa at 28 days and 49.8 MPa at 60 days. The density for this concrete is in the range of 1580 kg/m^3 to 1660 kg/m^3. The result for water absorption is in the range of 6.82% to 14.72%. However, the test results of weight loss is in the range between 0.30% to 0.43%.

1. Introduction

A better knowledge for the production of geopolymer cements based on natural materials (calcined kaolin, volcanic scoriae) and waste materials (slag, fly ash) becomes more crucial to improve the local economy. Ordinary Portland cement (OPC) producing high carbon dioxides (CO_2) emissions that cause global warming, hence geopolymer has been introduced to solve this problem. The utilization of geopolymer material as substituent to OPC, the mixture used like fly ash, silica fume and blast furnace slag sand can reduce the average of five times CO_2 compared to OPC [1]. The use of geopolymer has advantages like corrosion resistance, fire resistance, high compressive strength, tensile strength and rapid strength which enables geopolymer becomes as alternative material to OPC [2].

Lightweight aggregate concrete is defined as concrete of low density using lightweight aggregate such as expanded clay [3, 4]. LECA has small hole that could be absorbing and maintain environmental pollution [5, 6]. LECA is generated in kiln rotate horizontal about 1200°C by wet process, by utilizing bloated clay. LECA will be uses to replace coarse aggregate for the production of lightweight concrete [7].

Ordinary concrete typically contains about 12%, 8% mixing water, and 80% aggregate by mass. This means that in addition to 1.5 billion tons of cement, the concrete industry is consuming annually 9 billion tons of sand and rock together with one billion ton of mixing water [8].

LECA is used to replace the coarse aggregate and fly ash is used for the synthesis of green cement as alternative materials to produce a lightweight concrete in seawater exposure. Past study showed less study on the geopolymer concrete against seawater exposure. So this study is carried out to examine the performance of geopolymer lightweight concrete against seawater exposure.

Performance of fly ash based geopolymer incorporating LECA for lightweight concrete will be determined in term of compressive strength, water absorption, density, and weight loss compared to OPC lightweight concrete.

IOP Conf. Series: Materials Science and Engineering **267** (2017) 012012 doi:10.1088/1757-899X/267/1/012012

2. Materials and experimental methods

2.1 Mix Design

For this research, NaOH molarity of 12M and Na_2SiO_3/NaOH ratio of 2.5 are fixed [9]. The mass of fly ash, NaOH and Na_2SiO_3 are fixed for all samples. Table 1 shows the details of mix design for geopolymer and OPC.

TABLE 1. The details of concrete mix design.

Description (Geopolymer)	**Mix design**	**Description (OPC)**	**Mix Design**
Solid/liquid (Fly Ash/ Alkaline activator) ratio	2.0	Solid/Liquid (cement)	2.0
Na_2SiO_3/NaOH ratio	2.5	Water	2.5
Mass of Fly Ash (g)	798.0	Mass of Cement	798.0
Mass of NaOH (g)	114.29	Mass of Water	997.5
Mass of Na_2SiO_3 (g)	285.71		

The initial mix design for the aggregate sample is used to find the high compressive strength between the geopolymer with the proportion as shown in Table 2.

TABLE 2. The proportion materials used for GPC and OPC concrete.

GPC	Fly Ash (g)	Alkaline Activator		Aggregate	
		NaOH (g)	Na_2SiO_3(g)	LECA (g)	Sand (g)
	798.0	114.29	285.71	266	798
OPC	OPC (g)	Water (g)		Aggregate	
				LECA (g)	Sand (g)
	798.0	997.5		266	798

2.2 Experimental Procedure

The aggregate and the fly ash is mix together in the mixer. The mix is first dry mix to evenly distribute the fly ash and the aggregate. Then the solution of NaOH and Na_2SiO_3 are mixed to form alkaline activator. The activator is pour into the mixer to mix with the dry materials. After the mixing is homogeneous, the geopolymer paste is casted into 100mm x 100mm x 100mm mould. The samples is demoulded after 24 hours. Then the initial sample is weighted, then immerse in seawater according to the curing days of 3,7,14, 28 and 60 days. All samples will be tested for weight loss to measure the erosion of the cube, compressive strength, density, and water absorption. The test for water absorption is done according to BS 1881-122 (1983) [10]. The compressive strength test is conducted according to BS 1881-116 (1983) [11].

For weight loss testing, the sample cubes are weighed after removed from seawater, then the cube has been scraped off using a metal brush, and after being scraped, the cube sample is weighed a second time to get the difference result caused by erosion.

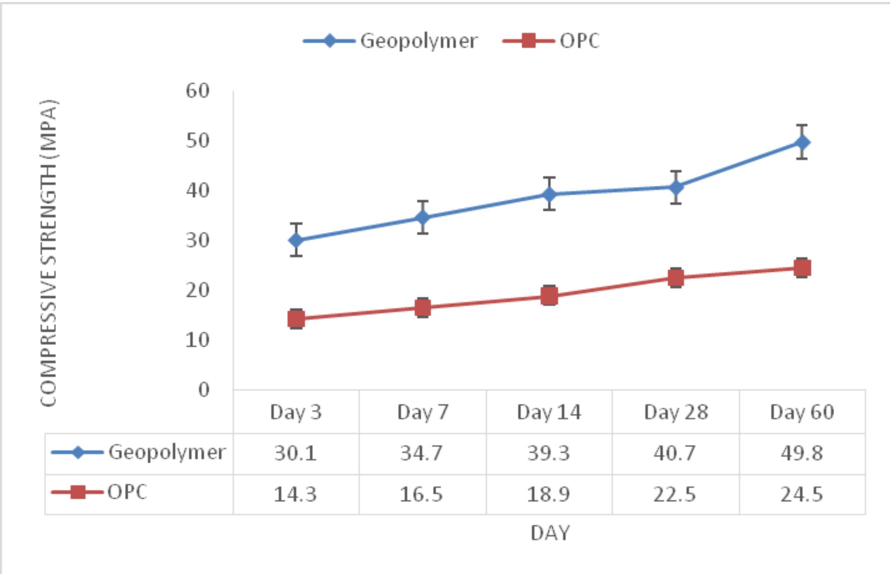
3. Result and discussion

3.1 Density

The density of concrete can be categorized either as normal, lightweight or heavyweight concrete. According to the result, the density of the OPC lightweight concrete and geopolymer lightweight concrete (GPC) are varied from 1580 to 1660 kg/m^3. The densities for both types of concrete are below than 1800 kg/m^3, which can be classified in the group of lightweight concrete.

3.2 Compressive Strength

Figure 1 shows the graph of compressive strength for geopolymer lightweight concrete (GPC) and ordinary Portland lightweight concrete (OPC) infilled LECA at various ages. The highest strength of GPC lightweight concrete is 49.8 MPa at 60 days and the second highest is 40.7 MPa at 28 days. Meanwhile for OPC lightweight concrete, the highest strength is 24.5 MPa at 60 days and 22.5 MPa at 28 days. The strength of GPC is two times (103%) higher than the strength of the OPC due to the chemical bonds of Si-O-Si and Si-O-Al produced through geopolimerization process which affect in increasing the compressive strength of GPC. The early strength of GPC at 3 days shows higher than OPC. During the laboratory works, the GPC samples were hardened rapidly than OPC. This shows that the GPC also applicable on site works and the time to complete the works can be reduced while the early high strength can be achieved [3, 4].
The results of compressive strength for GPC lightweight concrete shows high strength even using the LECA as a replacement of coarse aggregate and exposed in seawater exposure . The bond strength between geopolymer paste and LECA shows better bond strength and stable in seawater immersion compared to coarse aggregate.



	Day 3	Day 7	Day 14	Day 28	Day 60
Geopolymer	30.1	34.7	39.3	40.7	49.8
OPC	14.3	16.5	18.9	22.5	24.5

FIGURE 1. Compressive strength of GPC and OPC lightweight concrete.

3.3 Water Absorption

The water absorption for OPC concrete is in the range of 10.41% to 14.59% and the water absorption for geopolymer is in the range of 6.82% to 14.72%. Figure 2 shows the graph of water absorption of GPC and OPC lightweight concrete. Both results show not much difference for water absorption for seawater exposure. However, GPC shows slightly lower than OPC due to geopolymer gel produced in the GPC lightweight concrete which acts as a boundary to prevent the absorption of water in the concrete. The water absorption value was decreasing with the increasing of ages. The higher the curing days, the higher the matrix bonds presented in the samples and consume to high strength as proved in the compressive strength results.

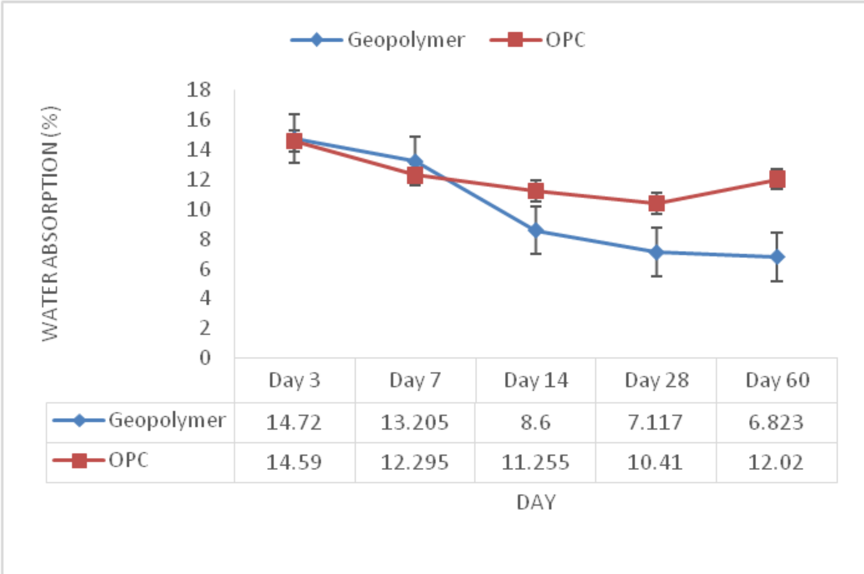


FIGURE 2. Water absorption results for GPC and OPC lightweight concrete.

3.4 Weight Loss

Weight loss test was performed to investigate the erosion of concrete when exposed to seawater. Figure 3 shows the graph of percent weight loss in the concrete at various ages. The lowest weight loss for OPC lightweight concrete is 0.135% at 3 days and the highest is 0.7% at 60 days. Then the lowest weight loss for GPC lightweight concrete is 0.303% at 3 days and the highest is 0.435% at 60 days. It shows that GPC lightweight concrete has lower weight loss at longer curing period in seawater compared to OPC lightweight concrete. This shows that GPC lightweight concrete have more durability in immersion of seawater. Further research should be done for longer curing period in seawater to investigate the weight loss of concrete.

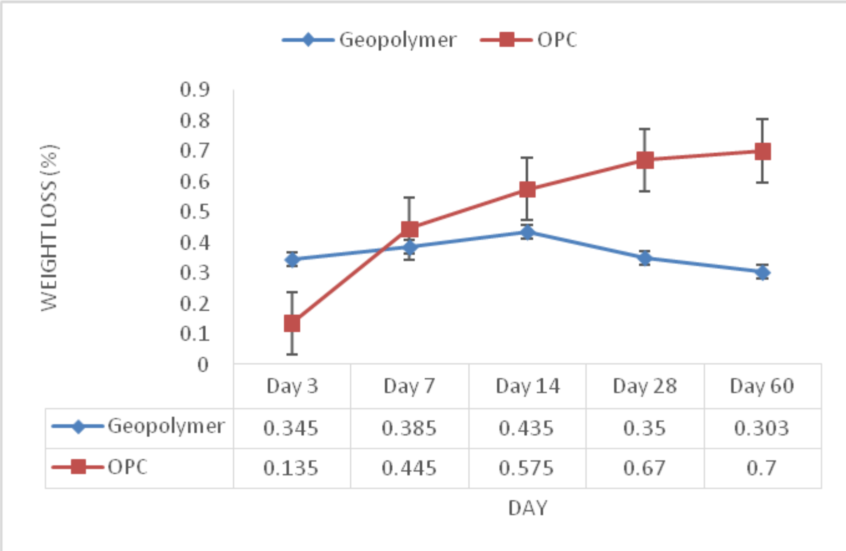


FIGURE 3. Percentage of weight for GPC and OPC lightweight concrete at various ages.

4. Conclusions

Based on the experimental result of this study, it can be concluded that:

1. In geopolymer concrete, the density of geopolymer concrete is below 1800 kg /m^3 which can be classified as lightweight concrete to be used as structure.
2. The highest compressive strength of GPC lightweight concrete is 49.8MPa at 60 days which is two times higher than OPC lightweight concrete infilled LECA and immersed in seawater.
3. In addition, the water absorption of GPC lightweight concrete is in the range of 6.82% to 14.72% which is merely difference with OPC lightweight concrete.
4. GPC lightweight concrete has lower weight loss at longer curing period in seawater compared to OPC lightweight concrete. The durability of GPC lightweight concrete is better than OPC concrete for longer curing period when immersed in seawater.

5. References

1. A. M. M. Al Bakri, H. Kamarudin, O. Abdulkareem, C. M. Ruzaidi, A. R. Rafiza, and M. N. Norazian. Applied Mechanics and Materials **110-116**, 734–739 (2011).
2. S. Lee, H. T. Jou, A. Van Riessen, W. D. A. Rickard, C. M. Chon, and N. H. Kang, N. H. Construction and Building Materials **52**, 221–226 (2014).
3. R. Arellano Aguilar, O. Burciaga, and J. I. Escalante. Construction and Building Materials, **24(7)**, 1166-1175 (2010).
4. S. Bazzaz Bonabi, J. Kahani Khabushan, R. Kahani, and A. Honarbakhsh Raouf. Materials and Design **64**, 310-315 (2014).
5. M. N. Sepehr, H. Kazemian, E. Ghahramani, A. Amrane, V. Sivasankar, and M. Zarrabi. Journal of the Taiwan Institute of Chemical Engineers, **45(4)**, 1821–1834 (2014).
6. A. Ardakani, and M. Yazdani. (2014). Applied Clay Science **93-94**, 28-34 (2014).
7. E. D. Murat, N. A. Hakan, and S. Cengiz. (2015). Construction and Building Materials **101**, 260–267 (2015).
8. G. Satheeshkumar and B. Selvam. International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE), **13(1)**, 536–541 (2015).

9. A. M. Mustafa Al Bakri, H. Kamarudin, M. Bnhussain, A. R. Rafiza and Y. Zarina, ACI Mater. Journal, **109 (5)**, 503-508 (2012).
10. British Standard BS 1881-122. Testing concrete, Method for determination of water absorption (1983).
11. British Standard BS1881-116. Testing concrete, Part 116: Method for determination of compressive strength of concrete cubes (1983).