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Performance of Geopolymer Concrete when Exposed to Marine Environment

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Abstract. Over the decades, concrete is widely known as the most resourceful construction material as it is suitable for many building applications. However, despite its ability to last hundreds of years in many applications, it has been proven that Portland cement concrete poses problems such as carbon dioxide emission and its durability when exposed to sea water, sulphuric soils or freezing weather. As a result, an alternative binder is in need to reduce these problem which nowadays, the uses of geopolymer concrete is promoted. Therefore, this research is intended to investigate the effect of marine environment towards geopolymer concrete and is compared to OPC concrete. By using the same curing conditions, both type of concrete is immersed in artificial seawater for total of 28 days before the properties such as water absorption, density and compressive strength is tested. As a result, despite the similar density, the GPC is found to have lower water absorption and higher compressive strength when compared to OPC concrete. As a conclusion, GPC exhibits a higher resistance to seawater thus, suitable for construction in marine environment when compared to OPC.

1. Introduction

Portland Cement is after water, the most utilized material in the world. It is largely used as the main material in producing concrete. The classic term of concrete refers to the mixture of Portland cement with the related materials such as water, aggregates and additives which when mixed together, are capable of producing concrete with desirable properties. Over the decades, concrete is widely known as the most resourceful construction material as it is suitable for many building applications. Previous studies has stated, from massive dams to the high skyscrapers all over the world, concrete was used as the main construction material [1].

However, despite its ability to last hundreds of years in many applications, it has been proven that Portland cement concrete poses problems such as carbon dioxide emission [2] and its durability when exposed to sea water, sulfuric soils or freezing weather. Major concerns is raised about its harmful impacts to the environment due to its significant contribution to the amount of greenhouse gas, resulting from the high volume of carbon dioxide emitted during its production [3].

As a result, an alternative binder are in need to reduce these problem which nowadays, the uses of geopolymer concrete is promoted. Geopolymer concrete is a new sustainable and environmental-friendly composite with great potential to replace conventional concrete mostly produced by ordinary Portland cement (OPC). The binder material used for geopolymer concrete such as fly ash and blast furnace are mostly the industrial waste or by-products containing high content of silica (Si) and aluminum (Al) which acted as precursor for geopolymerization [4]. Geopolymer technology also reveals the emission of carbon dioxide into the atmosphere is reduced by 80% as the result of aggregates and cement. Geopolymer also shows the ideal mechanical properties of concrete can be obtained such as high compressive strength, good acid resistance, low creep and low shrinkage [5].

2. Experimental Method

2.1. Raw Materials.

The fly ash used is attained from Manjung Power Plant, Lumut, Perak which is of low calcium, Class F is used as the base material of geopolymer and is equivalent to ASTM C618 while for Portland cement concrete, Blue Lion Cement is used. The chemical composition of fly ash and ordinary Portland cement obtained from the analysis as tabulated in Table 1.

Table 1: XRF analysis data of fly ash and ordinary portland cement

Component		SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	P_2O_5	SO_3	MnO
Percentage (%)	FA	52.11	23.59	7.39	0.88	2.61	0.78	0.42	0.80	1.31	0.49	0.03
	OPC	21.5	3.8	3.8	-	64.3	0.8	0.1	1.1	-	2.6	-

Based on this result, it proves that the fly ash used is type F fly ash where the sum content of SiO_2, Al_2O_3 and Fe_2O_3 is greater than 70%. Besides that, the difference in composition of fly ash and ordinary Portland cement is compared. It is found that the most abundant component found in fly ash is SiO_2 where the percentage is 52.11% while for ordinary Portland cement is CaO with 64.3%. The SiO_2 and CaO component plays a similar role where it helps in providing strength towards the concrete. However, according to past research, fly ash is particularly useful in marine structures since fly ash concrete since fly ash satisfies the conflicts (requiring both high C_3A and low C_3A) to resist chlorides and sulfates [6].

2.2. Mix Proportions and Mixing Process.

Based on past research [7-8], the most suitable mix proportion for geopolymer concrete is chosen where molarity of sodium hydroxide solution is 12M, ratio of sodium silicate to sodium hyroxide is 2.5 and the ratio of alkaline activator to fly ash is 0.5. While for ordinary Portland cement concrete, the cement to water ratio used is 0.5 [9]. The mix proportion of both geopolymer concrete and Portland cement concrete are tabulated in Table 2 below.

Table 2: Mix proportions of geopolymer concrete and Portland cement concrete.

Concrete	Ingredient	Weight (g)
Geopolymer concrete	12M sodium hydroxide	85.0
	Sodium silicate	215.0
	Fly ash	600.0
Portland cement concrete	Ordinary Portland cement	600.0
	Water	300.0

2.3 Moulding, Curing and Testing.
The fresh geopolymer are poured into (50x50x50) mm size cubes. The samples are left for 24 hours in room temperature before it is demoulded. Similar steps are also done to the fresh Portland cement. After that, the samples are immersed in artificial seawater (ASTM 1141-98) for in total of 28 days. For each 7, 14 and 28 days of immersion, weight of the samples were taken to determine the density, water absorption and tested in compressive strength testing machine.

3. Results and Discussions
It is observed that after 7 day of exposing the concrete to artificial seawater, there is precipitation inside the container containing Portland cement concrete sample as shown in Figure 1. However, there is no precipitation can be found inside the container containing geopolymer concrete sample. This may occur because of when the chloride diffuses into the Portland cement concrete, the hydroxide ion leaches out to maintain the electro neutrality of paste, which results in the portlandite solubility and can also cause decrease in the concrete strength [10].

Figure 1: Sample observation 7 days after exposure to artificial seawater

Samples are the observed again after taken out from the artificial seawater solution where the Portland cement concrete samples was found to exhibits some defects that only take place after the exposure. As shown in Figure 2, the Portland cement concrete shows presence of porosity and cracks at the surface of the sample while the exposure of artificial seawater has no significant effect occurred towards the geopolymer concrete sample.

Figure 2: Surface of Portland cement concrete (left) and geopolymer concrete (right) after artificial seawater exposure

3.1 Water Absorption
The result of water absorption of geopolymer concrete and Portland cement concrete after 28 days of immersion are presented in Figure 3. Based on the result, it is identified that the water absorption of geopolymer concrete is lower than of Portland cement concrete where the percentage obtained is 4.58% and 11.33% respectively.

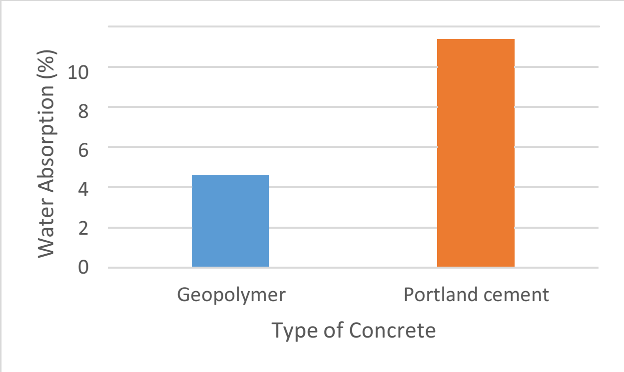

Figure 3: Water absorption result for both type of concrete

Water absorption with value ranged 3%-5% is classified as 'average' concrete. Low water absorption is a good indicator that there is limited open porosity that can inhibit high flow of water into the concrete [11]. However, the concrete will be classified as 'bad' if the value of water absorption is higher than 6% . Since Portland cement is a water-based concrete, it is expected that it will absorb more water if compared to geopolymer concrete [12].

3.2 Compressive Strength

The result on compressive strength of the geopolymer concrete and Portland cement concrete cube exposed to artificial seawater indicates that geopolymer concrete have better durability compared to Portland cement concrete as shown in schematics of Figure 5 where the compressive strength of geopolymer concrete at day 28 is 56MPa while Portland cement concrete is 46.86MPa.

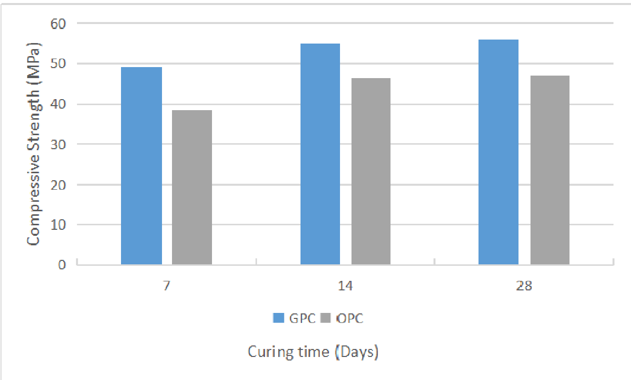

Figure 4: Compressive strength results

Since the reaction of pozzolanic takes time, it is able to be related to this result where as the curing time increases, the compressive strength also increases. The extended curing time intensify the geopolymerization mechanism thus increases the strength [13]. However, it is also observed that the difference of compressive strength between 7 day and 14 day of curing is higher when compared to the difference of compressive strength between 14 day and 28 day of curing. This shows that the concrete are steadily reaching its optimum compressive strength.

In addition, it is observed that there are no significant effect of the artificial seawater towards the compressive strength of the concrete. Sea water usually plays an important role in corrosion of steel. Past research had also noted that the increase time of curing in seawater had a massive impact on the deterioration of the reinforced steel inside the steel which will reduce the compressive strength of the concrete [14]. Since, there are no reinforcing steel used in this research, the effect of curing in seawater on compressive strength of the concrete are unable to be investigated properly.

4. Conclusion

The primary focus of this research has been to experimentally evaluate the durability of fly ash-based geopolymer concrete in marine environment and compared to ordinary Portland cement concrete. At early stage, research is done to identify the best formulation to produce fly ash-

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based geopolymer concrete and ordinary Portland cement concrete. Using the knowledge obtained, product is produced starting from raw material into a sample product for testing according to standard.

The key outcome expected is the better durability performance of geopolymer concrete. Therefore, by analyzing and comparing the behavior and properties of both type of concrete, it was observed that the fly ash-based geopolymer concrete is more homogeneous and well bonded than ordinary Portland cement concrete. Consequently, lower water absorption and higher compressive strength are obtained with geopolymer concrete.

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