The Compressive Strength of Green Polymeric Concrete

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***Abstract*— Many ways can be adopted to reduce the environmental pollution that is caused by production of Portland cement and the increase of waste materials. Geopolymer concrete containing crushed concrete waste aggregate (CCWA) is one of the methods to solve the problem. Waste Paper Sludge Ash (WPSA) and alkaline liquid as a binder have been used to replace the Portland cement to produce geopolymer concrete. The alkaline liquid used in geopolymerisation is the combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). In the present study, a mixture of geopolymer concrete specimens was adopted using 8M of sodium hydroxide (NaOH) and 4M of sodium silicate (Na_2SiO_3). The natural aggregate and CCWA was used as an aggregate in this study. The physical properties of each aggregate were determined. The geopolymer concrete specimens were cured at 60°C heat condition. There are 36 cube specimens of size 100mm dimension were prepared. The geopolymer concrete specimens were cast using the conventional cement concrete technique. The results of the studies show that the strength geopolymer concrete was in the range of 3-5 MPa.**

Index Term*— *Geopolymer; WPSA; CCWA; compressive strength

INTRODUCTION

The cement industry is held responsible for some of the carbon dioxide (CO_2) emissions, because the production of one tonne of Portland cement emits approximately one tonne of CO_2 into the atmosphere [1,2,3,4]. The CO_2 emitted to atmosphere causes the global warming hence contribute to climate change that can harm the human life.

In other hand, the concrete waste from the demolition of concrete building and construction activities was increased by the years. This waste material usually is dumped into the landfill which can shorten the life span of the landfill [14]. Realizing on environmental problem, there is urgency to replace cement and virgin aggregate as a based material in the concrete production. Utilization of waste material that generated from the industry has been studied [4]. These waste materials compose of element such as Si and Al could be activated with alkaline activator to produce compacted composite known as geopolymer.

The using of low calcium pozzolanic material such as fly ash from coal power plant as a source material for geopolymer thus far give an excellent performance in term of mechanical and durability performance [1-9]. However, there has less study on the high calcium pozzolanic such as WPSA in geopolymer. In the present study, the strength performance of high calcium WPSA geopolymer concrete containing CCWA was investigated.

I. MATERIAL AND EXPERIMENTAL DETAIL

A. Preparation of materials

In this study, coarse aggregate used in this study is natural aggregate (NA) and crushed concrete waste aggregate (CCWA). The CCWA was attained by crushing the waste cube from the construction site. Testing of the aggregate was conducted to determine the differences in the properties between the NA and CCWA. The physical properties of NA and CCWA were described in Table I. The maximum and minimum size of coarse aggregate used is 20mm and 10mm. The river sand was used as fine aggregate in this study.

TABLE I
PHYSICAL PROPERTIES OF NA AND CCWA

No.	Laboratory Test Conducted	Types of Aggregates	
		NA	CCWA
1.	Water Absorption (20mm) %	0.7	2.26
2.	Aggregate Impact Value (AIV) %	17.6	33.92
3.	Aggregate Crushing Value (ACV) %	24.1	29.3
4.	Specific Gravity (kg/m³)	2.64	2.44
5.	Bulk specific Gravity (SSD) (kg/m³)	2.65	2.68
6.	Apparent specific gravity (kg/m³)	2.68	2.7

WPSA from MNI industry was used as source material for geopolymer concrete production. The chemical analysis of WPSA is shown in Table II. The alkaline activator used for the polymerization process is sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3).

TABLE II
CHEMICAL PROPERTIES OF WPSA

Oxide	
SiO_2	26.25
CaO	66.39
Al_2O_3	14.26
Fe_2O	0.77
MgO	5.46
MnO	0.02
Na_2O	0.42
K_2O	0.35
SO_3	0.58
P_2O_5	0.33
TiO_2	0.54
LOI	14.83

B. Preparation of sample

In this experiment, the geopolymer concrete were produced in three (3) different batches, with each batches was different in term of molarity of sodium hydroxide used. The mixture of WPSA geopolymer concrete used in this experiment was shown in table 3. The geopolymer concrete samples were made of alkaline liquid to WPSA ratio of 0.35. The sodium hydroxide concentration used in this study is 8M. The sodium silicate concentration used is 4M. The amount of sodium silicate solution to sodium hydroxide solution ratio used is 2.5. Superplasticiser and extra water were used to improve workability of the geopolymer concrete mix.

TABLE III
MIX PROPOTION OF WPSA GEOPOLYMER CONCRETE

Material		Mix Proportion (kg/m^3)		
		Mixture 1	**Mixture 2**	**Mixture 3**
NA	**20mm**	814	407	-
	10mm	414	207	-
CCWA	**20mm**	-	407	814
	10mm	-	207	414
Fine sand		554	554	554
WPSA		408	408	408
Sodium silicate		103 (4 molar)	103 (4 molar)	103 (4 molar)
Sodium hydroxide		41 (8 molar)	41 (8 molar)	41 (8 molar)
Super plasticiser		6	6	6
Water		1800	1800	1800

The CCWA replacement used in each in this study are 50% and 100%. The conventional cement concrete technique was used to casting the geopolymer concrete samples. The fresh geopolymer concrete were cast into 100mm dimension cube mould.

The geopolymer concrete specimens were placed in the oven after 1 hour delay time. Before placing in the oven, the geopolymer concrete specimens were covered by the plastic to avoid extreme evaporation which can cause the concrete crack. The temperature used is 60°C. The geopolymer concrete samples were in the oven for 24 hour before taken out and placed at the ambient condition. The compressive strength of geopolymer concrete was tested at 3, 7, 14 and 28 days using a compression testing machine.

II. RESULT AND DISCUSSION

The compressive strength development of WPSA geopolymer concrete containing CCWA was shown in figure 1. As shown in the figure 1, the compressive strength of WPSA geopolymer concrete obtained from this study is low. This maybe cause by the low Si-Al content on the WPSA ashes which indicates that there are least reactivity or polymerization process happen in the mixture. This coincided with a statement by other researchers that the source material or ashes to produce a good geopolymer concrete requires a high Si-Al content [3-7].

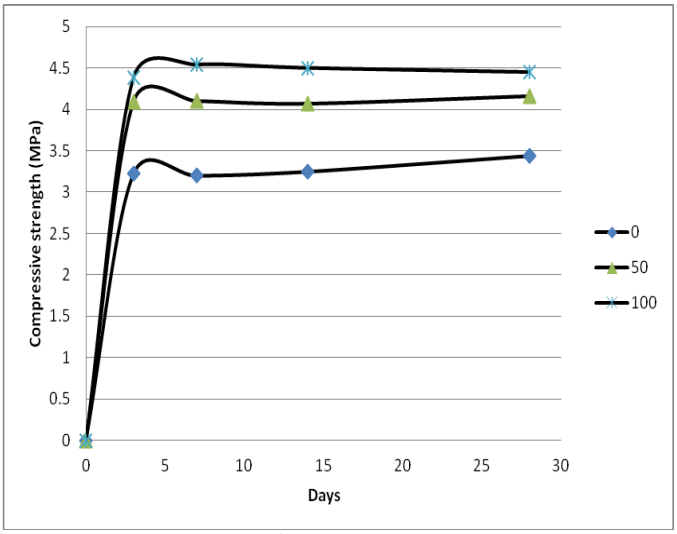

Fig. 1. Compressive strength of WPSA geopolymer concrete containing NA and CCWA

From the graph, it is found that the strength of WPSA geopolymer concrete containing NA, 50% CCWA and 100% CCWA at 3 days was 3.22, 4.09 and 4.38 MPa, respectively. At 7 days of curing time, the strength obtained was 3.2, 4.1, and 4.54 for NA, 50% and 100% replacement of CCWA, respectively. At the end of 28 days of curing time, the strength obtained was 3.44, 4.16 and 4.45 MPa for NA, 50% and 100% replacement of CCWA.

As comparison between the geopolymer concrete using the natural aggregate and CCWA as a coarse aggregate, the geopolymer concrete containing CCWA give a better strength of WPSA geopolymer concrete. The strength development of geopolymer concrete is higher when the percentage replacement of CCWA increased from 0% to 100%. These experimental results against the experiments conducted by researchers that use CCWA in producing fly ash geopolymer concrete and cement concrete [1, 11-13]. The report stated that the replacement CCWA in geopolymer concrete and cement concrete will reduce the mechanical performance of concrete. It is believed that the cement attached onto the surface of CCWA influence the strength of WPSA geopolymer concrete. Also, this maybe cause by the high water absorption of RCA which produce more compact WPSA geopolymer concrete mixture, wherein the ratio of alkali compounds and WPSA become lower than the geopolymer concrete using 100% NA. This result shows that the CCWA can be utilized as a coarse aggregate for geopolymer concrete production.

III. CONCLUSION

From the study, the following conclusion can be made:

1. The compressive strength produce by geopolymer concrete using WPSA as a source material give low mechanical strength due to low polymerization reactivity occurred in the mixture. However, it believed that this material can be used for a lower grade material in industry.
2. The using of CCWA in the WPSA geopolymer concrete up to 100% give a better result in compressive strength compared to WPSA geopolymer concrete using 100% NA.
3. Additional studies are required in the future to determine the potential of using WPSA as geopolymer product. The blending of other material with WPSA is needs to investigate in order to obtain a good mechanical characteristic of WPSA geopolymer product.

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