APPLICATION OF AGRO-WASTES IN GEOPOLYMER CONCRETE PRODUCTION. (PERIWINKLE SHELL ASH (PSA) AS CASE STUDY)

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ABSTRACT

The adverse effect of Ordinary Portland Cement (OPC) manufacture on the environment due to CO_2 emissions has forced a larger need for a more environmentally friendly binder for concrete production, such as a geopolymer binder. Geopolymer binder is made up of by-products containing alumina and silica, as well as hydroxide and silicate solutions. Periwinkle shell ash (PSA) was utilized to manufacture geopolymer concrete in this investigation. The alkaline liquid was made up of a mixture of NaOH and Na_2SiO_2. The purpose of this experimental investigation is to determine the suitability of PSA in manufacturing geopolymer concrete, which covers various properties of source materials, workability, compressive strength tests, and water absorption qualities of geopolymer concrete. Geopolymer concrete cubes of 100mm size were made and oven dried at 90°C for 24 hours before curing at ambient temperature for 7, 28, 56, and 90 days. It was revealed that, workability of the concrete increased as PSA content increased from 0 -100% (i.e. 102 – 119mm respectively). Also, increased duration of curing increased the concrete's compressive strength, however the strength decreased when the percentage of PSA increased. Water absorption increased as PSA levels rose in the mixture.

Keywords: Geopolymer Concrete, Periwinkle Shell Ash, Workability, Compressive Strength, Water Absorption

1.0 INTRODUCTION

Geopolymer is a binder that can be used in place of OPC in the manufacturing of concrete. It is manufactured from locally sourced components, primarily silica and aluminum, which is normally activated by a solution of alkaline. The chemical interaction of alumino-silica oxides with alkali polysilicates produces polymeric linkages, which is known as geopolymerisation.

In order to improve the geopolymerization process, high oven curing is usually required in manufacturing geopolymer concrete (Olivia et al., 2016). Concrete is a very vital material for construction works, since it is used to make roads, bridges, fences, pavements, and houses, among other things. OPC is the commonly used binder in concrete manufacturing. However, the OPC's production process pollutes the environment significantly by releasing a massive amount of CO_2 into the atmosphere (Davidovits 1994). Cement manufacturing releases around 1.5 billion tons of CO_2 on the environment each year, causing harms such as global warming, which poses a severe environmental danger (Lloyd et al., 2010). As a result, researchers are looking for an alternative cement that can be used as a binder in place of OPC, one that is more environmentally friendly and utilizes less raw ingredients (Shiva et al., 2017; Hardjito et al., 2007). The geopolymerization reaction results in the production of a rock-like structure, which is beneficial to the building sector (Malkawi et al., 2016).

Periwinkle shells are frequently available in huge quantities as waste products in practically all settlements in the Niger Delta area (Mmom et al., 2010). Periwinkle shell ash was used to partially substitute cement in concrete production by Dahunsi et al., (2002), and the results were positive. Yabefa et al., (2019) also reported on the strength qualities of a geopolymer binder using periwinkle shell ash, which demonstrated good strength development. As a result, the goal of this research is to create geopolymer concrete using PSA as source material.

2. MATERIALS AND METHODS

2.1 Materials

The various materials used are; metakaolin (MK), periwinkle shell ash (PSA), Na_2SiO_3 and NaOH, fine and coarse aggregates and water. Periwinkle shells were calcined at 800^oC and sieved 75-micron sieve size to obtain PSA. Metakaolin is a standard source material produced from calcining kaolin, which is rich in silica and alumina. A combination of Na_2SiO_3 and NaOH solution was employed as activator. Sodium silicate solution in the gel form was bought from a local commercial dealer. Its chemical compositions are; SiO_2 = 35%, NaO_2 = 16%, H_2O = 49% by mass, and has a specific gravity of 1.4. The NaOH in pellets form with 98% purity was used to prepare the solution of 12M concentration (i.e. 12M concentration means, $12 \times 40 = 480$g of NaOH/litre of solution (Ranjini *et al.*, 2014). The solution of the sodium hydroxide was prepared a day before the day it was used.

Fine aggregates used in the work were river sand free from all forms or organic or visual impurities conforming to the requirements of BS 882 (1982). The coarse aggregates were crushed granites. The physical properties of the aggregates are; (specific gravities; 2.38 and 2.63) and (bulk densities; 1760kg/m^3 and 1570kg/m^3) respectively.

2.2 Mix Design

In literature, most works on geopolymer are about the properties of the pastes or mortar measured with small dimensions (Hamid et al., 2016). Mix design for this study was taken based on the method reported by the modified guidelines for geopolymer mix proportions, hence, a mix ratio of 1:1.5:3 for grade 25 concrete was used (Anutadha et al.,2012; Shivakumar *et al.*, 2017), also, w/b ratio used was 0.1 (Ragan, 2014). The mixture of PSA and MK were used in the ratios; 0:100, 10:90, 20:80, 30:70, 40:60 and 100:0. Liquid to binder ratio used was 0.8 while Na_2SiO_3/NaOH ratio was 2.5. Mix proportions of the materials are presented in Table 2.1. Concrete Cubes of 100 mm were produced for the test. Newly casted cubes were demoulded after 24 hours at room temperature before oven curing at 90^{o}C for another 24 hours before specimens were allowed to cure at room temperature for 7, 28, 56 and 90 days before testing.

Table 2.1: Mix proportions

MIX ID	PSA:MK	PSA (kg/m^3)	MK (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)	Na_2SiO_3 (kg/m^3)	NaOH (kg/m^3)	H_2O (kg/m^3)
N1	0:100	0	381	554	1294	122	49	38
N2	10:90	39	343	554	1294	122	49	38
N3	20:80	77	305	554	1294	122	49	38
N4	30:70	115	267	554	1294	122	49	38
N5	40:60	153	229	554	1294	122	49	38
N6	100:0	381	0	554	1294	122	49	38

3. RESUSLTS

3.1 Chemical Analysis of PSA and MK

Chemical compositions of PSA and MK where analyzed using the X-Ray Flourescence analyzer, the result is presented in Table 3.1.

Table 2.1: Chemical Analysis of PSA and MK

Constituent Oxide	**PSA (%)**	**MK (%)**
Silica Oxide (SiO_2)	28.10	65.45
Aluminium Oxide (Al_2O_3)	14.60	28.0
Ferrous Oxide (Fe_2O_3)	7.60	1.42
Calcium oxide (CaO)	39.10	3.23
Magnesium oxide (MgO)	1.02	0.00
Sodium oxide (Na_2O)	1.87	0.00
Potassium oxide (K_2O)	0.25	0.00
Lead oxide (P_2O_3)	0.52	0.14
Manganese oxide (MnO)	0.84	0.00
Sulphite (SO_3^{-2})	5.28	0.79
Vanadium oxide (V_2O_5)	0.03	0.0056
Copper oxide (CuO)	0.036	0.0003
Zinc Oxide (ZnO)	0.05	0.073
Loss on Ignition (LOI)	5.26	1.22

3.1 Sieve Analysis of the Sand

Table 3.1 presents the physical properties such as gradation and fineness modulus

Table 3.1: Particle size Distribution of Fine Aggregates

S/NO.	**Sieve Number**	**Weight Retained (g)**	**%wt. Retained**	**%wt. Passing**	**Cumm. %wt. Ret.**
1.	4.75	7.2	1.81	98.19	1.81
2.	2.36	34.7	8.71	89.48	10.52
3.	1.18	96.2	24.16	65.32	34.68
4.	850	49.9	12.53	52.79	47.21
5.	600	47.9	12.03	40.76	59.24
6.	425	41.6	10.45	30.31	69.69
7.	212	50.6	12.71	17.6	82.4
8.	150	29.9	7.51	10.09	89.91
9.	75	35.6	8.94	1.15	98.85
10.	Pan	4.6	1.15		100
	Total	**398.2**			

$$\text{Fineness modulus} = \frac{\text{Cumulative percentage weight retained}}{100} = 2.61$$

3.1 Workability

Slump test results are; 102, 113, 119, 127, 129, and 131mm for N1, N2, N3, N4, N5, and N6 respectively.

3.2 Compressive Strength

Table 3.2 presents the Compressive strength test result.

Table 3.2: Compressive Strength

Sample ID	PSA:MK	7 days (N/mm^2)	28days (N/mm^2)	56 days (N/mm^2)	90 days (N/mm^2)
N1	0:100	22.43	26.30	27.30	27.40
N2	10:90	20.90	25.0	25.87	26.20
N3	20:80	18.90	22.20	22.43	22.50
N4	30:70	12.70	19.10	20.13	20.30
N5	40:60	12.10	18.0	18.21	19.50
N6	100:0	10.90	13.7	14.10	14.40

3.3 Water Absorption Test

Table 3.2 presents the results for the average water absorption capacities of the various test specimens at 90 days.

Table 3.2: Water Absorption

Sample ID	PSA:MK	Wet Wt. (kg)	Oven Dry Wt. (kg)	Water Gain	Average %Absorption
N1	0:100	2.42	2.38	0.04	**1.82**
N2	10:90	2.38	2.30	0.08	**3.47**
N3	20:80	2.43	2.33	0.10	**4.14**
N4	30:70	2.49	2.37	0.12	**4.91**
N5	40:60	2.48	2.25	0.11	**5.10**
N6	100:0	2.39	2.26	0.13	**5.91**

4. DISCUSSIONS

4.1 Chemical Analysis of PSA and MK

The chemical compositions of PSA and MK where analyzed using the XRF analyzer, the result is presented in Table 3.1. The oxide summation for both PSA and MK are 50.22 and 95.69% which qualifies them as class C and F pozzolans respectively in accordance with ASTM C618. The specific gravities of PSA and MK were also found to be 2.50 and 2.51 respectively.

4.1 Sieve Analysis of Sand

Table 3.1 presents the physical properties such as gradation and fineness modulus which was tested in accordance with IS:2386. The fine aggregates have a fineness modulus of 2.61 which can be classified as medium class sand.

4.2 Workability

Slump test was done to determine the fresh concrete workability. The slump values measured are; 102, 113, 119, 127, 129, and 131mm for the different mixtures such as N1, N2, N3, N4, N5, and N6 respectively. The result showed that, the concrete workability increased as the content of PSA increased.

4.3 Compressive Strength

Compressive strength test result is presented in Table 3.2. The average strength at 7, 28, 56 and 90 days of the geopolymer concrete samples made of different mixtures (i.e. N1 – N6) produced good results. The result showed that, the strength increased generally with increase in concrete curing days, and reduced with increase in PSA content in the mixture. It was observed that, the strengths obtained in mix N1 – N3, (i.e. 0 - 20% of PSA) were 26.3, 25.0, 22.20 N/mm^2 respectively which met the required designed strength of the concrete in 28 days of curing.

4.4 Water Absorption Test

Table 3.2 presents the average water absorption capacities of the various test specimens at 90 days, which was done based on BSS 1881:122. The PSA based geopolymer has water absorption capacities ranging from 1.82%, 3.47%, 4.14%, 4.91%, 5.1% and 5.91% for the various mixtures from N1- N6 respectively. Therefore, the percentage water absorption increased with increase in PSA.

5. CONCLUSION

The study ended with the conclusions that, the increase in PSA content in the mixture enhanced the workability. The increase in PSA content reduced the compressive strength of the concrete in the curing duration in the various mixes. The compressive strength of concrete samples with 10%, 20%, and 30% of PSA also had a substantial strength that can be used as a structural concrete. The test result on water absorption of the concrete specimens showed that, percentage absorption of water increased with increasing content of periwinkle shell ash. However, 10 - 20% PSA in the mixture did not have much negative effect on geopolymer concrete with respect to water absorption.

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