EFFECT OF EXTRA WATER ON THE COMPRESSIVE STRENGTH OF PERIWINKLE SHELL ASH BASED GEOPOLYMER MORTAR.

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ABSTRACT

The effect of extra-water on geopolymer mortar samples under compressive loading was investigated in this study. The PSA processed at 800°C was used as the source material. The mortar samples were made with moulds of 70.6mm^2 cube according to the British standard. The samples were tested after 7, 14, and 28 days of curing. River sand was used as fine aggregates. Mix 1 and 2 were prepared with W/B ratios of 0.18 and 0.13 respectively. The river sand used for the study had specific gravity of 2.60 and fineness modulus of 4.98. The 28-day compressive strengths for Mix 1 (19.9, 18.1, 17.4, 16.5, 14.2, and 8.2 N/mm^2) and Mix 2 (25.0, 22.9, 18.3, 17.5, 16.2 and 15.2 N/mm^2) showed, Mix 2 performed better than the Mix 2 with less extra-water content. The paired t-test used in the study showed that, there was significant improvement on the strength of the mortar samples when the W/B ratio was reduced from 0.18 to 0.13 since the calculated value of t = 3.112 > tabulated t at 5 df = 2.015.

Keywords: Geopolymer, mortar, extra-water content, compressive strength, periwinkle shell ash,

INTRODUCTION

One major challenge faced by the humans here on earth is the issue of environmental pollution. Environmental pollution is the introduction of non- environment friendly substances called impurities in to the atmosphere, which can come in the solid, liquid or gaseous form from different industries into the environment. In the construction industry, cement is the major ingredient used for the production of concrete. Cement is indispensable for construction activities, hence its of high relevance to the global economy, therefore, the production of cement is increasing by 2.5 percent annually due to the high demand for cement. However, cement production requires high level of energy consumption and also, it emits a lot of CO_2 into the environment due to the extreme heat required in its manufacturing process. Greenhouse gas (such as CO_2) emission is associated with cement manufacturing. The calcination of limestone, which is made of calcium carbonate greatly contributes to the emission of CO_2 in to the environment (Olivia *et al.* 2011). Hence, the high demand for cement across the globe has increased its production causes global warming, as it pollutes the environment.

Olivia *et al.,* (2011) explains the growing concerns of CO_2 emission during cement manufacturing as it involves extraction of raw materials. In view of this, the concept of geopolymer which uses local wastes as raw materials was developed to be used as an alternative to Portland Limestone Cement (PLC) in concrete production. Hence, the use of local wastes such as Periwinkles Shells in this study is also a measure of environmental pollution control of the waste. Increase in quantity of extra water in GPC leads to decrease in mechanical properties of geopolymer mortar.
In 1978, Davidovits came up with the idea that, aluminatesilicate materials can be activated with alkalines to form binders which can be used in place of PLC (Davidovits 2002). Geopolymer is formed through a polymerization reaction, where water is consumed through the process dissolution but later given out.

If the activator concentration in a geopolymer mixture is high enough, then, availability of enough water contained in the mixture will enhance the process of dissolution, though, the reaction will be slowed down (Zuhua *et al*. 2009). Hence, there is need for a point when the content of water in the mixture will be enough for dissolution to take place without diluting the activator to impair the process of polymerization. Literature is sparse on the effects of water-binder ratio on the properties of geopolymers. Hence, this experimental study intends to investigate the effect of extra-water on the compressive strength of a geopolymer binder incorporating PSA as the source material.

2.0 MATERIALS AND METHODS

2.1 Materials

Periwinkle shells were calcined at a temperature of 800°C to obtain the periwinkle shell ash (PSA) while Kaolin was calcined at a temperature of 700°C to obtain metakaolin (MK). After calcining, the source materials were then ground and sieved with 75-micron BS sieve size.

The activator was a mixture of Na_2SiO_3 and NaOH solution. The Na_2SiO_3 solution in the gel form whose chemical analysis is shown in Table 2.1 was obtained from Sumateq Ceramics Ltd in Lagos. The NaOH solution of 12M concentration was used.

The fine aggregates used in this study was a river sand sourced from the Bodija market in Ibadan.. The specific gravity of the river sand used in this study was 2.60. The sieve analysis test result is presented in Table 2.2.

Table 2.1: Chemical analysis of Na_2SiO_3

Constituents	Result
Silica oxide	35%
Sodium oxide	16%
Water	49%

2.2 Mix Proportions

The mix design for this study was done in accordance with the method used by Usha *et al.* (2016) to arrive at the mix proportions which are presented in Table 2.2, and 2.3 designated as Mix 1 and 2 respectively. The only variation between the two is the extra water content (i.e. water/binder ratios for Mix1 and 2 are 0.18 and 0.13 respectively). The PSA and MK were blended in the ratios; 0:100, 10:90, 20:80, 30:70, 40:60, 100:0 denoted with A, B, C, D, E, and F respectively. The mortar specimens were cast and allowed for a rest period of 24 hours before demolding and cured at an elevated temperature of 90°C for 24 hours before ambient temperature curing. The test was after 7, 14 and 28 days UTM at the materials laboratory of civil engineering, University of Ibadan, Nigeria.

Table 3.8; Mix proportions for Mix1

Sample ID	PSA:MK	L/B	SS/SH	W/B	B/FA	PSA(g)	MK(g)	FA (g)	Na_2SiO_3 (g)	NaOH (g)	Extra H_2O	Molarity (NaOH)
Mix1A	0:100	0.8	2.5	0.18	0.33	0	200	600	114.3	45.7	36	12M
Mix1B	10:90	0.8	2.5	0.18	0.33	20	180	600	114.3	45.7	36	12M
Mix1C	20:80	0.8	2.5	0.18	0.33	40	160	600	114.3	45.7	36	12M
Mix1D	30:70	0.8	2.5	0.18	0.33	60	140	600	114.3	45.7	36	12M
Mix1E	40:60	0.8	2.5	0.18	0.33	80	120	600	114.3	45.7	36	12M
Mix1F	100:0	0.8	2.5	0.18	0.33	200	0	600	114.3	45.7	36	12M

Table 3.18: Mix proportions for Mix2

Sample ID	PSA:MK	SS/SH	L/B	W/B	B/FA	PSA (g)	MK (g)	FA (g)	Na_2SiO_3 (g)	NaOH (g)	Extra H_2O	Molarity (NaOH)
Mix2A	0:100	0.8	2.5	0.13	0.33	0	200	600	114.3	45.7	26	12M
Mix2B	10:90	0.8	2.5	0.13	0.33	20	180	600	114.3	45.7	26	12M
Mix2C	20:80	0.8	2.5	0.13	0.33	40	160	600	114.3	45.7	26	12M
Mix2D	30:70	0.8	2.5	0.13	0.33	60	140	600	114.3	45.7	26	12M
Mix2E	40:60	0.8	2.5	0.13	0.33	80	120	600	114.3	45.7	26	12M
Mix2F	100:0	0.8	2.5	0.13	0.33	200	0	600	114.3	45.7	26	12M

3.0 RESULTS AND DISCUSSIONS

3.1 Particle Size Distribution of Fine Aggregates

Table 3.1 presents the sieve analysis result of the river sand.

Table 3.1: Sieve Analysis of fine aggregates

Sieve Number	Weight Retained (g)	Percentage wt. Retained	Percentage wt. Passing	Cumm. wt. %Ret.
4.75	7.2	1.81	98.19	1.81
2.36	34.7	8.71	89.48	10.52
1.18	96.2	24.16	65.32	34.68
850	49.9	12.53	52.79	47.21
600	47.9	12.03	40.76	59.24
425	41.6	10.45	30.31	69.69
212	50.6	12.71	17.6	82.4
150	29.9	7.51	10.09	89.91
75	35.6	8.94	1.15	98.85
Pan	4.6	1.15		100
Total	**398.2**			

Fineness modulus of fine aggregate = $\frac{\text{Cumulative percentage weight retained}}{100}$

Fineness modulus = $\frac{1.81+10.52+34.68+47.21+59.24+69.69+82.4+89.91+98.85}{100} = 4.98$

The fineness modulus of the river sand was 4.98, hence, the sand can be classified as medium class sand, which is suitable for mortar production for structural works.

3.2 Compressive Strength

The compressive strength test results for mortars for Mix 1 and 2 are presented in Table 3.2 and 3.3 respectively. The result showed that, the strength of the geopolymer mortar reduced with increase in the PSA content, and increased with increase in the curing duration in both mixtures.

The 28-day compressive strengths are Mix 1 (19.9, 18.1, 17.4, 16.5, 14.2, and 8.2 N/mm^2) and Mix 2 (23.0, 22.9, 18.3, 17.5, 16.2 and 15.2 N/mm^2).

Table 3.2: Compressive strength of Mix 1 samples

Sample ID	**7 days (N/mm^2)**	**14 days (N/mm^2)**	**28 days (N/mm^2)**
Mix1A	18.1	18.4	19.9
Mix1B	17.3	17.7	18.1
Mix1C	16.5	17.4	17.4
Mix1D	15.4	15.4	16.5
Mix1E	14.7	15.0	14.2
Mix1F	7.30	7.62	8.2

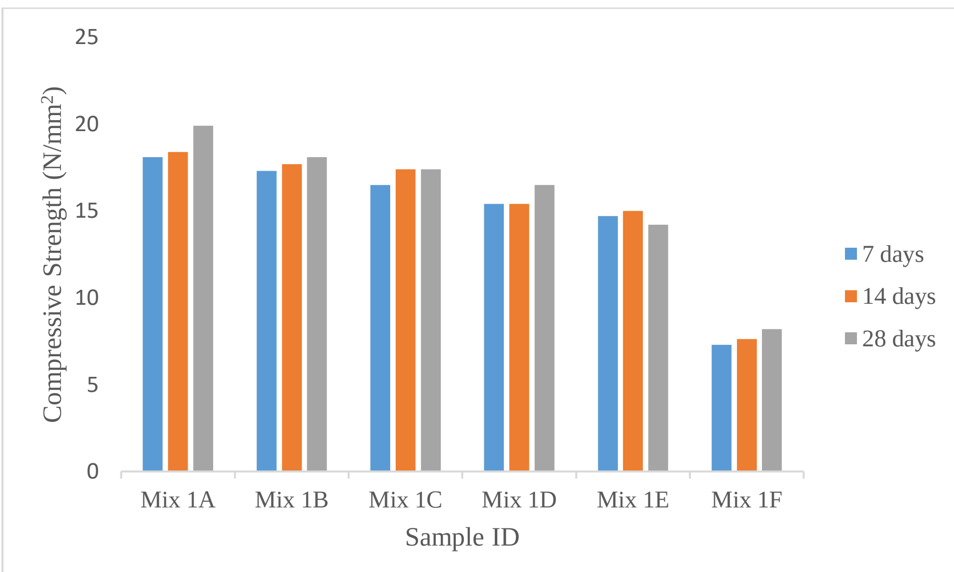

Figure 3.1: Compressive strength of samples produced with Mix1

Table 3.3: Compressive strength of Mix 2 samples

Sample ID	7 days (N/mm²)	14 days (N/mm²)	28 days (N/mm²)
Mix2A	22.9	24.4	25.0
Mix2B	22.0	22.6	22.9
Mix2C	16.7	17.6	18.3
Mix2D	14.8	17.5	17.5
Mix2E	13.0	15.9	16.2
Mix2F	12.2	14.8	15.2

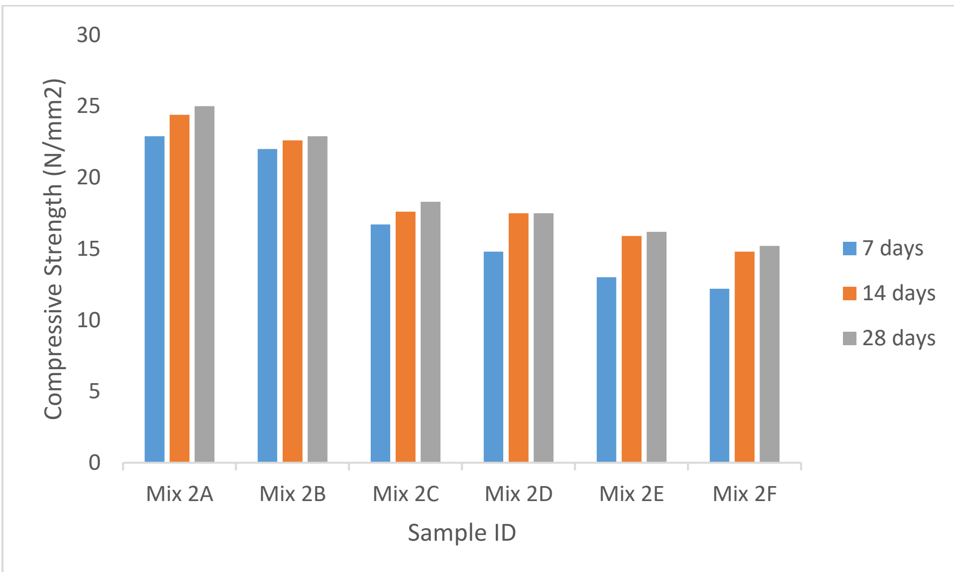

Figure 3.2: Compressive strength of samples produced with Mix2

3.3 Comparison of 28-day Compressive Strengths of Mix 1 and Mix 2

The effect of the extra-water content on the 28-day compressive strengths of the geopolymer mortar samples are presented in Figure 3.2 as contained in Table 3.2 and 3.3 respectively. Mix 1 and Mix 2 are made of SS/SH = 2.5, and L/B = 0.8, but with different W/B ratios of 0.18 and 0.13 respectively. Hence, the compressive strength test result showed that, the strength of the mortar increased with reduction in the extra water content of the mixture in all cases. This was also confirmed by Mathew (2016) in another study. When a reduced water content is used in the geopolymer mixture, the alkaline activator concentration tends to increase in the system, thereby accelerating the geopolymerization process, hence, increasing the final strength of the geopolymer mortar (Olivia 2011).

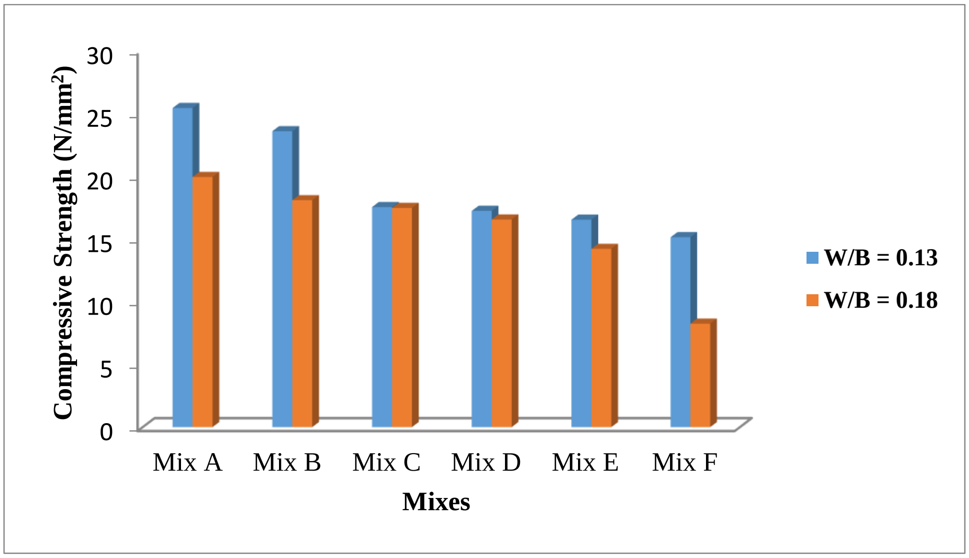

Figure 3.3: Effect of water content on compressive strength of 28-day mortar samples

3.4 Test on the variation of the 28-day compressive strengths of Mix 1 and Mix 2

To obtain the significance of difference between a 28-day compressive strength of the geopolymer mortar made with different contents of water (i.e. W/B ratios; 0.18 and 0.13) in Mix 1 and Mix 2 in Table 3.2 and 3.3 respectively. Let the both mixes be designated with X_1 and X_2 respectively. The test is shown in Table 3.4. The 0.05 significance level paired t-test was used in this study as reported by Arora *et al.* (2009). Computation of test statistic is shown in Table 3.4.

Table 3.4: Computation of test statistics

S/NO.	X_1	$X_{2.}$	$D = X_{1.}-X_{2.}$	$D^2=(X_1-X_{2.})^2$
1.	19.9	25.0	5.1	26
2.	18.05	22.9	4.85	23.52
3.	17.43	18.3	0.87	0.757
4.	16.51	17.0	0.49	0.24
5.	14.17	16.2	2.03	4.12
6.	8.21	15.2	6.99	48.86
			$\sum D = 20.24$	**$\sum D^2 = 103.5$**

From Table 4.25;

$$\text{Mean difference: } \bar{D} = \frac{\sum \bar{D}}{n} \qquad (4.4)$$

$$\text{Mean difference: } \bar{D} = \frac{\sum \bar{D}}{n} = \frac{20.24}{6} = 3.373$$

$$\text{Variance: } S^2 = \frac{\sum D^2}{n - 1} - \frac{(\sum D)^2}{n\,(n-1)} \qquad (4.5)$$

$$\text{Estimated Variance: } S^2 = \frac{103.5}{6.1} - \frac{(20.24)^2}{6(6-1)}$$

$$= \frac{103.5}{5} - \frac{409.6}{6\times 5}$$

$= 20.7 - 13.65 = 7.05$

$= \sqrt{7.05} = 2.655$

Standard Error of Difference: $S.E(\overline{D}) = \frac{S}{\sqrt{n}}$ (4.6)

Standard Error of Difference: $S.E(\overline{D}) = \frac{S}{\sqrt{n}} = \frac{2.655}{\sqrt{6}} = 1.084$

Test Statistic: $t = \frac{\overline{D}}{S.E(D)}$ (4.7)

Test Statistic: $t = \frac{\overline{D}}{S.E(D)} = \frac{3.373}{1.084} = 3.112$

Significance level: $\alpha = 0.05$

The value of t at $\alpha = 0.05$, where, degree of freedom is 5 for one tailed test is $t = 2.015$.

Since the calculated value of $t = 3.112 >$ tabulated t at 5 df = 2.015. This means that, there is significant improvement on the compressive strength of the geopolymer mortar when the water content is reduced from 0.18 to 0.13, which is in accordance with the report given by Mathew (2016) in a similar study.

4.0 Conclusion

The conclusions drawn from the study are.

i. Increasing the number of curing days also increased the strengths of the geopolymer mortar samples made with Mix 1 and 2.

ii. The geopolymer mortar strength of samples made with Mix 2 (W/B = 0.13) performed better than Mix 1(W/B = 0.18).

iii. The 0.05 significance level paired t-test showed, there was significant improvement on the compressive strength of the mortar samples when the W/B ratio was reduced from 0.18 to 0.13 since the calculated value of $t = 3.112 >$ tabulated t at 5, df = 2.015.

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