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Evaluating Effect of Palm Kernel Shell Ash Additives on Compresive Strength Properties of Geopolymer Concrete of Clay from Ire Ekiti and Ikere Ekiti

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

With abundance and viability of Clay soil at Ire Ekiti and Ikere Ekiti which can be use as geopolymer source material and abundance of Palm kernel shell ash (PKSA) in south western Nigeria, this study is to evaluate effect of PKSA- an agricultural waste, as additive on compressive strength of Ire and Ikere clay geopolymer concrete. Palm kernel shell was ashed at 650°C for 2 hours at the furnance of glass technology department, federal polytechnic, Ado- ekiti. Ire and Ikere Clay was similarly procured, air dried and calcined in a furnace at 750°C for 2 hours. The Pulverized calcined clay as source material for the geopolymer with 12M of NaOH and Na_2SiO_3, with NaOH to Na_2SiO_3 at ratio 2:5. River sand and 12 mm aggregate size of granite were adopted as filler in the geopolymer concrete mix at ratio 1:2:3. PKSA in mass percentages of the Ire and Ikere Clay in order of 0, 7.5 and 15% were added to the geopolymer concrete mixes for different specimen and maturities of 7, 14 and 28 days. Compressive strength of Ire Clay geopolymer concrete with PKSA as additives at room temperature has its highest compressive strength at 7.67 N/mm^2 at 28 days

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with 15% additive while that of Ikere Clay Geopolymer has 10 N/mm² at 28 days maturity with 15% additive.

Keywords: Compressive strength; filler; geopolymer; palm kernel shell ash; waste.

1. INTRODUCTION

Geopolymers have received considerable attention because of their low cost, excellent mechanical and physical properties, low energy consumption and reduced "greenhouse emissions" during the elaboration process. As Geopolymer concretes don't contain Portland cement and the powder binder used is typically an industrial waste or a minimally-processed natural material, they can have lower carbon dioxide emissions than classic concrete and be presented as environmental friendly [1,2]. However, despite the release of carbon become the main criteria used in the assessment of environmental impacts, there are also other aspects that affect the environment, such as fresh water and marine ecotoxicity, human toxicity, ozone depletion, acidification, and eutrophication [3,4].

Davidovits [5] proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminium (Al) in a source material of geological origin or in by-product materials such as fly asdah and rice husk ash to produce binders. Geopolymer concrete is concrete which does not utilize any Portland cement in its production. Geopolymer concrete is being studied extensively and shows promise as a substitute to Portland cement concrete. Research is shifting from the chemistry domain to engineering applications and commercial production of geopolymer concrete.

The main constituents of Geopolymer are source material rich in silicon (Si) and aluminum (Al) and alkaline activator solutions. The source materials for Geopolymer could be natural minerals such as kaolinite, clays, and industrial by-products such as rice husk ash, GGBFS, fly ash, silica fume, and red mud. The alkaline liquids used as an activator for the geopolymerisation process may be a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate (Na_2SiO_3) solution. Water in a geopolymer mixture plays no significant role in the chemical reaction taking place and aids in producing a workable mixture (Sreevidya 2014).

Palm kernel Shell ash (PKSA) is obtained from byproducts of oil palm fruit processing [6,7]. The resulting ash generated from the burnt Palm Kernel shell is known as Palm kernel shell ash. Much is not known about PKSA as a pozzolanic material [8]. The major factors affecting geopolymerization are identified as type and nature of raw materials, alkaline activators and curing conditions [9,10]. This is aimed at comparative evaluation of impacts of PKSA as additives in geopolymer concrete based on synthesized geopolymer gel of alternative source materials of Ire and Ikere Clay cured at room temperature.

2. MATERIALS AND METHODS

2.1 Source Material

Clay sourced for Ire and Ikere Ekiti were calcined at 750^0C in the furnace for 2 hours. Palm kernel shell sourced from local palm oil industry was ashed at 650^0C for 2hrs in furnace in accordance with Olulope et al., [11]. The fine aggregate (river sand) and Coarse aggregate used were procured from vendors within the community. Procured Aggregates were subjected to sieve analysis for particle size distribution, while the PKSA passing through BS sieve no 200 were used.

Sodium Hydroxide and Sodium Silicate mix solution was recommended as alkaline activator for synthesis of geopolymer gel, and were used.

The adopted mix ratio of 1:2:3 geopolymer concrete by mass whereby geopolymer gel is 1 part, fine aggregate 2 parts and coarse aggregate takes three parts by weight. PKSA was introduced as additive in proportion of 0, 7.5 and 15% in respective batches of the mix.

Three trial samples of 50*50*50 mm³ specimens were casted for different maturity of 7, 14 and 28 days. The 50*50*50 mm^3 samples were cured at room temperature for each of the batch of geopolymer concrete with or without additives sourced from Ire and Ikere Ekiti Clay.

2.2 Laboratory Testing

Compressive strength on the cured specimens of geopolymer concrete was conducted at Afe Babalola University, Department of Civil Engineering Laboratory. The compressive strength test was carried out by using an electronically operated wizard basic compression test machine. The specimens were placed in the hydraulic testing frame and a force was applied until the specimen cracked. The prism halves were centered laterally to the platens of the machine within ± 0.5 mm and placed longitudinally so that the end face of the prism overhangs the platens by about 10 mm. The maximum force applied and the dimensions of the specimen were then recorded and compressive strength calculated. The final compressive strength results were as a result of arithmetic mean of the values of six individual test samples.

3. RESULTS AND DISCUSSION

3.1 Physical Properties

Table 1 shows the specific gravity, grain size distribution and colour of the additive and source materials.

3.2 Chemical Composition

Table 2 shows The Chemical Composition of Ire and Ikere clay constitutes 58.96% and 58.27% Silicon Oxide and 19.85% and 32% Aluminium Oxide respectively. PKSA on the other hand is constituted of 55.2% and 12.1% Silicon Oxide and Aluminium Oxide respectively. SiO_2 is considerably very high in PKSA related to Al_2O_3 in order of 73.8%. Remarkable difference between Ikere and Ire Clay is seen from the relative of aluminium oxide and calcium oxide.

3.3 Compressive Strength

Fig. 1 shows the compressive values of the Ire clay geopolymer concrete with PKSA as additive samples showing 7, 14 and 28 days maturity cured at room temperature in open air. The samples compressive strength increased with maturity, sample without additives increase in compressive strength from 7 days to 28days from 1.71 N/mm^2 to 2.82 N/mm^2 with 38.9% increase in compressive strength.

At 7 days maturity PKSA of 7.5% additive improved the compressive strength by 110% while 15% PKSA addition improved the strength by 145% increase. At 14 days maturity PKSA of 7.5% additives improved the compressive strength by 133% while 15% PKSA additives improved the strength by 150% increase. At 28 days maturity PKSA of 7.5% additives improved the compressive strength by 152% while 15% PKSA additives improved the strength by 147% increase. Increasing Percentage of PKSA as additives impact positively in compressive strength gain with maturity of the geopolymer concrete.

Impacts of PKSA additives on Geopolymer concrete based on Ikere Clay Source Materials is presented in Fig. 2. The Samples increase with maturity. Samples without additives increase compressive strength from 7 days to 28 days with a 53% increase in compressive strength. At 7 days of maturation, the addition of 7.5% improved the compressive strength by 4%, while the addition of 15% PKSA increased the strength by 46%. At 14 days maturity, the addition of 7.5% PKSA improved the compressive strength by 112%, while the addition of 15% PKSA increased the strength by 165%. At 28 days maturity, the addition of 7.5% PKSA improved the compressive strength by 100%, while the addition of 15% PKSA improved the strength by 150%. PKSA as Additives generally has positive on compressive strength on geopolymer

Table 1. Physical properties of geopolymer base material and additives

Properties	Specific gravity	Colour
Ire clay	2.57	Reddish Brown
Ikere clay	2.79	White
Palm kernel shell ash	1.38	Black

Table 2. Chemical composition of geopolymer base material and additives

Oxides	SiO_2	Al_2O_3	Fe_2O_3	CaO	P_2O_5	K_2O	MgO	Na_2O	MnO	CuO	LOI
Ire Kaolin	58.96	19.85	3.31	0.36	0.11	0.23	0.38	1.91	0.07	0.21	11.26
Ikere Kaolin	58.27	32.00	1.32	1.21	0.02	1.96	0.11	0.76	0.02	0.01	10.67
Palm kernel shell ash	55.20	12.1	7.92	5.52	3.150	4.32	3.30	2.10	0.20	0.05	2.21

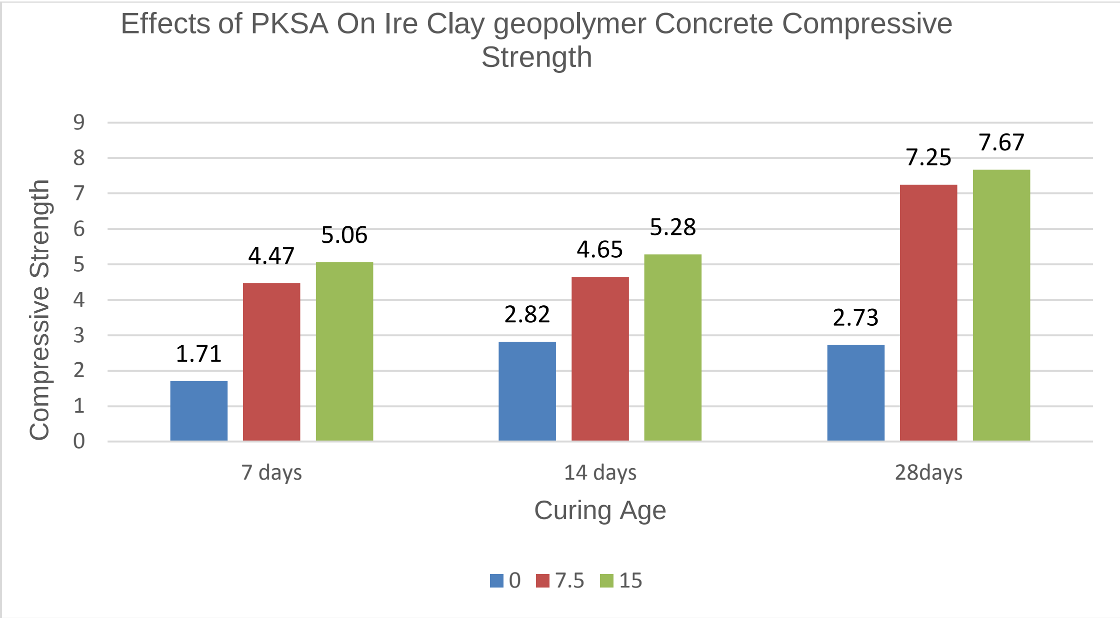

Fig. 1. Effects of PKSA on Ire Clay geopolymer concrete compressive strength cured room temperature

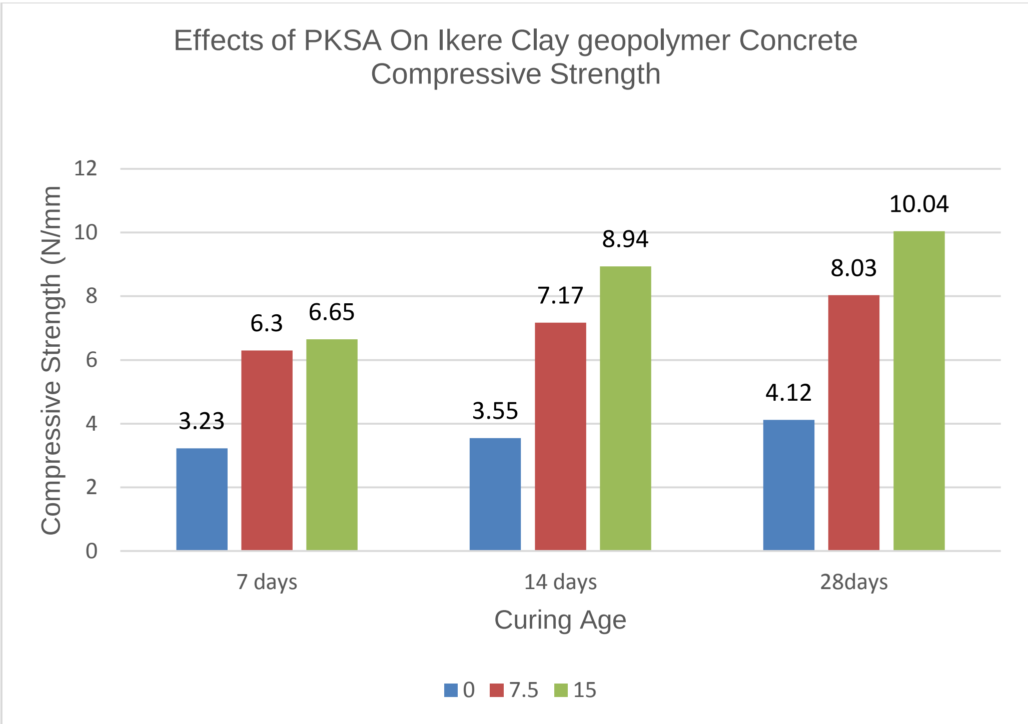

Fig. 2. Effects of PKSA on Ikere Clay geopolymer concrete compressive strength cured at room temperature

concrete based on the alternative source materials. The Impacts on Geopolymer concrete based on Ikere Clay Source materials is more pronounced with maximum compressive strength 10 N/mm² while Ire clay based Geopolymer concrete PKSA additives of 15% at 28 days maturity has maximum compressive strength of 7.8 N/mm². Increase in compressive strength of the cubes with corresponding increase in PKSA can be associated with presence of relative higher percent of calcium oxide of about 5% in the additives compared to Ire clay 0.36% and 1.21% in Ikere clay.

4. CONCLUSIONS

It can be concluded that Increasing Percentage of PKSA as additives impact positively in compressive strength gain with maturity of the geopolymer concrete at room temperature. This is edging geopolymer adaptability and application towards usage in developing and under-developing countries for the indicative viability of Ire and Ikere clay as a geological source for geopolymer and agricultural waste of PKSA as additives improving the compressive strength of the produced geopolymer samples. Impacts of PKSA can be associated with presence of relative higher percent of calcium oxide of about 5% in the additives compared to Ire clay 0.36% and 1.21% in Ikere clay. Further Study will reveal the specific role of calcium oxide in polymerization of geopolymer concrete based on Ire and Ikere Clay cured at room temperature. This study confirmed that geopolymer concrete with PKSA additives based on geological source is feasible to be cured at room temperature with some potential structural applications.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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