BOOK OF PROCEEDINGS

For the

ENUGU STATE UNIVERSITY OF SCIENCE & TECHNOLOGY, AGBANI

FACULTY OF ENVIRONMENTAL SCIENCES (FES)

1ST Research Conference –RECONFES 001

Theme:

ONLY One Earth

On Wednesday, 8th June, 2022

At ESUT Business School, Enugu

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FORWARD

World Environment Day (WED) is an annual programme instituted 50 years ago in 1972 at Stockholm. It was formed to take place on the 5th June every year. It is aimed at living sustainably in harmony with nature, bringing transformative changes through policy and our choices towards cleaner and greener lifestyles.

The faculty organized this conference being our own way of joining the moving train and the good intentions of the proponents of WED. The conference is a gathering of intellectuals across the academic landscape of the faculty of environmental success in various universities.

In the quest to add value to our academic pursuit, this year's theme "Only One Earth" drew a lot of articles from across the universities contributing to the growth of environmental sustainability.

The conference would not have been such a resounding success without the support of eminent professors, erudite scholars; men and women who have the interest of our common good (the earth) at health. And of course our LOC ably led by Dr E. Nnadi. A conference provides a veritable meeting ground for paper presentation, discussions and socializing.

The quality papers presented in this conference will be published in our faculty journal "African Research Journal of the Environment", after they have been thoroughly reviewed.

We thank all the participants for their invaluable contributions

Arc Dr. Augusta Emenike
Ag Dean Fes

Acknowledgement

Our sincere appreciation goes to the visitor and the governor of Enugu state, Rt. Hon. Ifeanyi Ugwuayi who gave ESUT a dynamic, digital and hardworking Vice Chancellor at this critical time. The academic and body language of Prof Michael-Aloysius Okolie gave us confidence to embark on this huge task. We have confidence that the university's performance shall be applauded in the next NUC ranking.

We commend the humble and focused dean of the most online friendly faculty in ESUT, A/Prof Augusta Emenike for her strong will and teaming up with the right minds towards moving the faculty forward. We specifically appreciate the keynote speaker in person of Prof Kingsley Ogboi, the dean of Faculty of Environmental Sciences, UNEC. Thanks for making it to this event despite your tight schedule.

Appreciation also goes to the Professors in our faculty, the scientific committee members, the LOC, the authors, the delegates and most remarkably, the faculty staffs and the postgraduate students for their cooperation and contributions towards the success of this conference.

Finally we are grateful to the Director and staff of Esut Business School for perfect logistics and necessary supports provided. Any error found in this work is unintended and therefore highly regretted. Be free to send your comments to reconfes@esut.edu.ng as we look forward to future events. Kindly accept our best within the national contraints.

Thanks

Dr Ezekiel Ejiofor Nnadi

For: Editorial/LOC Team

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Strengthening Mortar by Using a Ternary Geopolymer Binder Made of Cassava Peel Ash, Metakaolin, and Rice Husk Ash

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Abstract

An alternative new ternary geopolymer mortar was developed to resolve a traditional mortar problem which exhibits several disadvantages, including poor strengths and surface microcracks and the CO_2 air pollution. The ternary binder was produced using Cassava peel ash (CPA), Metakaolin (MK), and Rice husk ash (RHA) activated with an alkaline mixture of sodium silicate (Na_2SiO_3) and 9 M NaOH in a mass ratio of 2.5. Five different mix proportions of CPA, MK, and RHA were used to fabricate the ternary geopolymer mortars (TGPM's). The water-to-binder ratio was 0.35. The mortars were heat cured for 24 h at 60℃ and then aged under room temperature. Mortar flow and compressive strength was tested. The results showed that the sample C70M20R10, which contained 70% CPA, 20% MK, and 10% RHA, exhibited high compressive strength (50.02 N/mm^2 and 54.74 N/mm^2) without any crack at 28 days and 56 days respectively, after being cured for 24 hours at 60°C; however, the C90M07R03 mortar with optimal strength of 55.32 N/mm^2 and 58.93N/mm^2 for 28 days and 56 days respectively, showed some surface cracks. This ternary binder will be useful from an environmental viewpoint, as it reduces the waste disposed in landfills and helps prevent global warming. Production of new geopolymer binder of mortar as alternative to traditional cement binder with high early and normal strength from low cost waste materials and earth explored materials, less potential of cracking, less energy consumption need and low carbon dioxide emission.

Keywords: Alkaline mixture, Cassava peel ash, Strength, Metakaolin, Rice husk ash Ternary geopolymer mortars,

1 Introduction

Many waste products are produced in the agricultural and industrial sectors, causing disposal issues as well as the most serious environmental threat, global warming. The

cement industry is another energy-intensive business that contributes to the problem by emitting greenhouse gases such as carbon dioxide (Heath et al., 2014). As a result, several writers are focused on the use of agricultural and industrial waste products, as well as earth explored materials, as a substitute to ordinary Portland cement (OPC) to overcome problems like disposal and global warming for the sake of sustainable development. Waste products such as cassava peel ash, rice husk ash, bagasse ash, silica fume, fly ash, metakaolin, and others have been found to be beneficial in mortar and concrete applications; however, these wastes can only be used as a partial replacement for OPC and cannot completely replace it (Chalee *et al.,* 2013; Chalee *et al.,* 2010; Krammart & Tangtermsirikul, 2004). This as lead to the quest for geopolymer technology.

Cassava peel is produced at a rate of 6.8 million tonnes per year, with 12 million tonnes tageted in 2020. (Raheem *et al*., 2020). CPA fits the requirements for a pozzolana, according to studies, and meets the ASTM C618 (2020) criterion of a minimum of 70% for pozzolanas (Ofuyatan *et al*., 2018 & Ogunbode and Akanmu, 2012). Due to alkali activated materials and amorphous products, modern cement concrete binders are a very complex chemical material. However, modern geopolymer concrete is being investigated as an alternative to cement concrete, and geopolymer binders with improved strength are being produced using various alternative materials. Davidovits (1991) established the notion of geopolymers, which can be made by reacting silica and alumina with alkali-activating solutions.

The creation of strong alumina-silicate polymeric structures is caused by the reaction of silica with alumina, which is freed by hydroxides and silicates of sodium or potassium as the alkali-activating solution. The alkali-activating solution frequently requires additional heat to speed the dissolution process, which can improve the characteristics of geopolymers due to the delayed reactivity of the source materials (Kovalchuk *et al.,* 2007). The qualities of each source materials can be advantageously exploited in ternary binders, for example, through interactions between the ternary beginning components, resulting in better compressive strength, stability, and durability (Xu and Van Deventer 2002). This research aims to show that employing a ternary geopolymer binder (TGPMs) based on CPA, MK, and RHA instead of single or binary binders or Portland cement can improve the strength of geopolymer mortars.

2 Materials and Methods

2.1 Geopolymer Precursors: CPA, MK, and RHA

As stated previously, CPA, MK, and RHA were used as precursor to produce the ternary geopolymer binder in this study.

The CPA used in this study was gotten from dried Cassava peel calcinated at 750°C in an electrical furnace for 2 hours and it is Dark Ash in colour. The specific gravity of CPA is 2.3. The Cassava peel was collected as a waste material generated from cassava plant from Doko village in Lavun LGA of Niger state. Table 1 summarizes the chemical composition of CPA.

The MK sample used was produced in the laboratory by the calcination of earth explored kaolin, sourced from Alkaleri Local Government of Bauchi State, Nigeria. The calcination was performed at 750°C in an electrical furnace for 2 hour, yielding calcined kaolin clay or MK. The sample is grinded to 75 micrometers. MK has a distinctive off-white colour close to that of the parent kaolin. The appearance of kaolin has changed from pure white to floral whitish after dehydrocyclization process. The specific gravity of MK is 2.2 the chemical compositions of MK were determined using X-ray Fluorescence Spectroscopy (XRF). The XRF results revealed that the major constituents of MK are silicon oxide (SiO_2) and alumina oxide (Al_2O_3). Other components include ferric oxide (Fe_2O_3), calcium oxide, magnesium oxide, potassium oxide, etc. The typical chemical composition of MK is depicted in Table 1.

Table 1: Chemical compositions of CPA, MK and RHA (mass%).

Materials	SiO_2	Al_2O_3	CaO	SO_3	Fe2O3	Na2O	K2O	TiO2	MnO	MgO	LOI
MK	72.39	20.35	7.01	-	1.12	0.34	3.12	0.90	0.02	0.12	2.35
CPA	80.83	14.77	34.24	0.83	1.55	0.06	5.50	-	0.05	0.05	0.20
RHA	83.76	10.54	1.26	0.00	1.32	0.00	1.50	0.20	0.00	1.55	2.92

The Rice husk used was obtained from a local grain mill in Garatu village along Minna-Bida Road, Bosso LGA, in Niger State. The collected rice husk was then burnt in open air with a locally fabricated incinerator. The resulting RHA was dried and sieved to eliminate larger materials and to lessen the carbon content. A local milling device was used to ground the resulting burnt RHA particles to a size smaller than 150μm. Finally, the grounded ash was sieved with a 75μm sieve and particles passing through were used as the RHA for the experiment. Figure 1 presents the pictorial view of CPA, MK and RHA.

Figure1: Sample of CPA, MK and RHA

Figure 2 illustrates the XRD patterns of CPA MK and RHA. The XRD pattern of CPA revealed a pronounced broad hump with diffraction peaks at 2α values in the range of 27-56^{o}. Few sharp crystalline diffraction peaks indicates its dominant amorphous phase and crystalline phases of 111,220,330. The XRD pattern of MK and RHA demonstrates an outstanding crystalline phase material with obvious detectable quantities of kaolinites and silica.

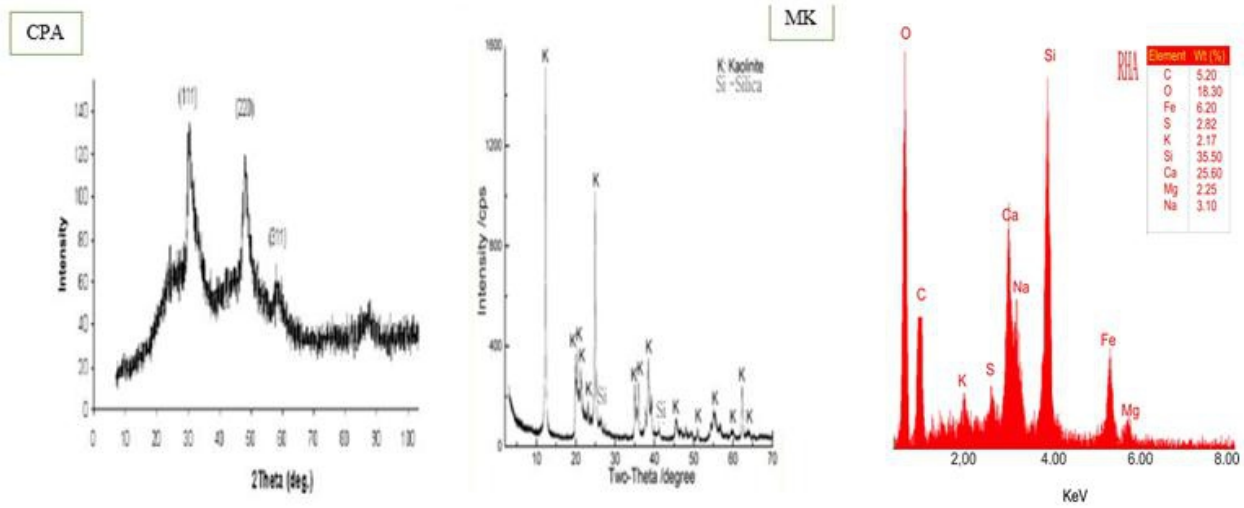

Figure 2: XRD of (a) CPA (b) Mk and (c) RHA

Figure 3 displays the SEM images of CPA MK and RHA used in this study. The surface morphology of CPA clearly revealed gelatinous appearance with irregular globular shaped particles as shown in Figure 3a, whereas MK and RHA manifested irregular pellet-like and angular particles arranged disorderly (Figure 3b&c).

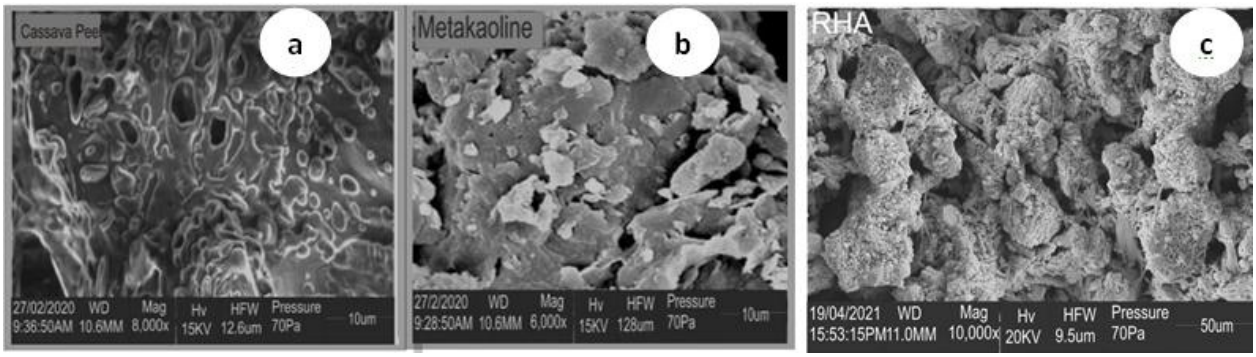

Figure 3: SEM of (a) CPA (b) MK and (c) RHA

2.2 Fine aggregate

Siliceous River Sand was used to prepare all mortar specimens. Finess modulus of the aggregate and specific gravity were discerned to be 2.6 and 2.4 respectively.

2.3. Alkali solution

Sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) were obtained commercially. The NaOH pellets used had a purity of 99%. A Na_2SiO_3 solution with a silica ratio (Ms) of 2 was added to 9 M of NaOH, and the final mixture was used as the alkaline activator. Further, CEM II cement (42.5 N) of Dangote brand was used as the reference to compare the properties of the fresh and hardened mortar samples produced using the developed binder.

Moreover, natural river sand was used as the fine aggregates for the geopolymer mortar.

2.4 Design of mixing proportion of GPM's binder

The research investigated the varying composition of solid binder as independent variable on the engineering properties of ternary blend Alkali Activator mortar. The control variable of this research is the variation in binder composite, total five mortar samples were cast with increasing CPA content of 10 %, 30 %, 50 %, 70 % and 90 %. While the remaining contents was two-third of MK and one-third of SHA as shown in Table 2

Table 2: Mix proportion of Alkali Activator Mortar for optimum CPA content

Mix ID	CPA (%)	MK (%)	SHA (%)	W/B Ratio	FA	Na_2SiO_3	NaOH
C90M07R03	90	7	3	0.35	2.5	0.25	0.1
C70M20R10	70	20	10	0.35	2.5	0.25	0.1
C50M33R17	50	33	17	0.35	2.5	0.25	0.1
C30M47R2	30	47	23	0.35	2.5	0.25	0.1

3	0	7	3	5	5		
C10M60R30	10	60	30	0.35	2.5	0.25	0.1

2.5 Preparation of specimens

The solid binder (CPA, RHA & MK) was blended prior to mixing of mortar. Each material was weighted precisely according to the experimental program to ensure the accuracy of mixing proportion. After that, the blended binder was further mixed with fine aggregate (river sand). The mixing process was continued until the binder and sand were uniformly blended. Alkali activator and water was then added into the prepared binder to form the alkali actvated fresh mortar. Demoulding oil was coated on the steel moulds prior to the moulding process to ensure the ease of demoulding process of hardened specimens, in order to prevent any possible damage to occur on the specimens. Next, adequate compaction on the specimen during the moulding process until a smooth and leveled surface was achieved was done to minimize the presence of trapped air voids within the fresh mortar. The specimens were then placed for hardening process at room temperature for 24 hours (resting period). After that, all the hardened AAM's was demoulded on the next day, and cured in oven at 60^{o}C for 24 hours. Afterwards, the samples were cured in ambient temperature for the remaining curing days. The strength properties of specimens was tested at different ages of curing (3, 7, 28 and 56 days), in concomitant with the control and constant variable of the mortar mix as shown in Table 3.

Table 3: Control and constant variable of the mortar mix

Variable	
Constant Variable	**Control Variable**
Water/binder ratio: 0.35 Binder-Sand ratio: 1:2.5	**CPA Content** (10 %, 30 %, 50 %, 70 %, 90 %)
Alkali dosage: 0.35 Na_2SiO_3/ NaOH = 2.5 Curing method: Oven curing	

2.6 Experimental testing method

The flow table test was carried out to study the flow ability (BS EN 1015-3:1999) of readily mixed fresh AAM's. The strength properties of alkali-activated (CPA-MK-RHA) ternary blended AAM with varying replacement level of the solid binder was tested by compressive test (ASTM C109/C109M, 2020). The compressive strength

properties of AAM was collected at day 7, 28 and 56 using 50 mm mortar cube specimen.

3. Results and Discussion

3.1 Flowability and setting time test

Throughout the experiment, the rapid setting of ternary-based GPM was noticed as shown in the Table 4. The fresh mortar began to set within five to twenty minutes (5-20 mins) right after thorough mixing for the C90M07R03 mix followed by C70M20R10, C50M33R17, C30M47R23 and C10M60R30 with the initial and final setting times of twenty and sixty minutes (20-60 mins), twenty-five and sixty-five minutes (25-65 mins), thirty and hundred minutes (30-100 mins), forty-five and one-twenty minutes (45-120 mins) respectively.

It was later discovered that the GPM had a very flash setting in comparison with the reference mortar (CGPM) having it initial and final setting times to be one and half hours and three hours respectively. Hence, the results also revealed that at a decrease in the CPA content then the setting time increases.

Furthermore, the result also showed a descending trend in the spreading width as observed with a decrease in the replacement levels of CPA. Higher CPA content exhibits higher workability and faster settings of the GPM. Hence, it was discovered that the RHA incorporation contributed to the reduction in the spreading width as a result of its hygroscopic nature and thereby accelerate the geopolymerization of the specimens This is similar to the of Gao *et al.*, 2016. Lower spreading width achieved by increasing the replacement level of MK-RHA attributed to the content of CaO and thus accelerate the geopolymerization as its rapid reaction with alkali activator (Khan *et al.*, 2016).

The initial flow table result for C90M7R3 was 220 mm as shown in plate 1 and table 4. However, the spreading width of the subsequent mixes were found to be slightly reducing from 220 mm to 210 mm, 200 mm, 190 mm, 150 mm and 140 mm for C70M20R10, C50M33R17, C30M47R23 and C10M60R30 respectively. This can be explained by rapid dissolution of CaO as reacted with the activator and on the other hand, the inclusion of the RHA prolong the setting times due to the slow rate of decomposition in RHA particles at ambient temperature (Wang *et al.,*2015).

Table 0: Fresh Properties of ternary blended GPMs

Variables	Spreading Width (mm)	Setting time (min)	
		Initia	Final

		1	
PCM	220	90	180
C90M07R03	210	5	20
C70M20R10	200	20	60
C50M33R17	190	25	65
C30M47R23	150	30	100
C10M60R30	140	45	120

3.2 Compressive Strength Test

Compressive strength of control mortar cubes and geopolymer cubes cured at 3, 7, 28, and 56 days were illustrated in Table 5, all the data have been averaged by three numbers of specimens among the different specimens. It was observed from Table 5 that the compressive strength increases as the curing period increases. From the table it is observed that geopolymer mortar has shown higher compressive strength than control specimens. The results showed that the sample C70M20R10, which contained 70% CPA, 20% MK, and 10% RHA, exhibited high compressive strength (50.02 N/mm^2 and 54.74 N/mm^2) without any crack at 28 days and 56 days respectively, after being cured for 24 hours at 60°C. However, the C90M07R03 mortar with optimal strength of 55.32 N/mm^2 and 58.93N/mm^2 for 28 days and 56 days respectively, showed some surface cracks.

Table 5: Compressive Strength Test

Mix ID	3 days	7 days	28 days	56 Days
PCM	9.00	24.00	42.07	44.55
C10M60R30	11.22	19.00	30.21	34.58
C30M47R23	15.90	32.10	41.16	43.62
C50M33R17	22.32	39.17	47.32	48.01
C70M20R10	36.43	43.23	50.02	54.74
C90M07R03	36.12	47.30	55.32	58.93

Refering to Table 5, an upward trend in the compressive strength was observed with the increase in replacement level of CPA. Highest compressive strength achieved was C90M07R03 of 58.93 N/mm^2 at 56 days. As the CPA contents increased from 10% to 90% at every 20% interval, the compressive strength thus increased by 26.60%, 13.02%, 5.34%, and 9.58%, respectively at 28 days. This can be explained by the addition of CPA content, which contributed higher rate of Ca^{2+} ions in the geopolymer matrix (Nath and Sarker, 2014). Hence, higher rate of geopolymerization in forming calcium-alumina-silicate-hydrate gel (C-A-S-H) with higher Ca/Si ratio (Soutsos *et al*, 2016). Not only that, CPA dissolved high amount of Ca^{2+} and Al ions to the system, it allowed the substitution of Al into (C-S-H) chain, thus turning it into (C-A-S-H) matrix. Hence, it may lead to formation of complex matrix with crosslinking between the tobermorite chains (Salih et al., 2015).

The 7days compressive strength of C70M20R10 and C90M07R03 had achieved 84.29 and 83.04% of the 28 days strength. Higher initial strength development in C70M20R10 and C90M07R03 attributed to high reactivity of CPA as a calcium (Ca)

bearing material accelerated the dissolution and hydration process of geopolymer at early stage (Nath and Kumar, 2013). In the contrary, the lowest initial strength was achieved to be 11.22 N/mm^2 at 3 days of C10M60R30 mix, with about 67.55% of its 56 days strength. Approximately 68.94% lower in 3 days compressive strength as in compared to C90M07R03. The synthesis of chemical composition in C10M60R30 was high in SiO_2/Al_2O_3 and low Ca/SiO_2 ratio attributed to abundant of Si in RHA. Silicon component tend to dissolve in slower rate as compared to Al component, resulting in gradual strength development (Ranjbar, Mehrali, Alengaram, *et al.*, 2014). Geopolymer with high SiO_2/Al_2O_3 ratio tends to prolong its final strength development to later stage, by condensation between silicates species due to different rate of dissolution with Al and Ca components (Yusuf *et al.*, 2014). However, C30M47R23 and C50M33R17 developed higher initial strength at 3 days with relatively high replacement level of PFA at ambient temperature can be explained by the two possible mechanism of geopolymer hydration reaction. Firstly, the high reactivity of CPA particles tend to accelerate the hydration process, thus separate hydration reaction from one another can be seen by formation of CPA matrix around the unreacted MK, which was much likely to be seen in C10M60R30 as shown in Table 5. Secondly, both of the binders‟ reactions had occurred simultaneously, whereby the reactions of GGBS particles have activated the fly ash at ambient temperature.

4. Conclusions

The following deductions can be drawn out of this study;

- The results revealed that the setting time prolonged as the replacement levels of RHA-MK increased at a decrease in replacement levels of CPA.
- Compressive strength test results indicated that alkali-activated ternary blended binder (CPA-MK-RHA) geopolymer mortars have shown superior performance to the control system (CEM II - portland cement mortar).
- By considering the good strength obtained from this investigation, alkali-activated ternary blended binder (CPA-MK-RHA) geopolymer mortars can be used as a substitute material for OPC.
- The use of NaOH in combination with Na_2SiO_3 improved the curing efficiency and resulted in accelerated curing. The strength of the ternary blended GP mortars was determined by the mixing proportion of the starting materials, their degrees of fineness, and the alkaline activators used. Mortar C70M20R10 and C90M07R03 exhibited high compressive strengths of 54.74 N/mm^2 and 58.93N/mm^2. Thus, the optimal mixing proportion for producing the TGPM's was determined to be 70% CPA, 20% MK, and 10% RHA (without cracks) and 90% CPA, 7% MK, and 3% RHA (with surface microcracks). However, further investigations must be performed to gain a better understanding of the formation of microcracks in the TGPM's that showed high strength.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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