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VOLCANIC ASH FROM PIDONG, BOKKOS-MANGU ROAD: EVALUATING ITS POZZOLANIC POTENTIAL FOR CONSTRUCTION APPLICATIONS

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Abstract: *Ascertained chemical properties and application of Volcanic Ash (VA) in concrete would help a researcher's judgement in exploring a viable source of pozzolana to be used in cement replacement for concrete production. This study was aimed at investigating the pozzolanic potential of volcanic ash of the Jos Plateau sourced from Pidong along Bokkos – Mangu Road. Mix ratio of 1:2:4 and 0.6 water cement ratio (w/c) was used for the production of the test concrete cubes. Twenty-one concrete specimens, each for 7- and 28-days curing, were produced with three test cubes for control specimens and three each for cement replacement of 5%, 10%, 15%, 20%, 25% and 30% respectively. The concrete specimens were produced by mixing the required weight of cement, volcanic ash, aggregate and water, after which it was poured into an oiled mould of size 150mmx150mmx150mm and compacted in three layers of 50mm each by ramming using steel rod, after which they were vibrated using vibrating machine. The test cubes were demoulded after 24 hours, weight and immersed in a curing tank filled with water for 28days at room temperature. After 7 and 28 days the test cubes were removed, weight and air dried. Failure load was obtained by crushing the test cubes using the compression machine in the Building Laboratory of the Department of Building, University of Jos, Plateau State. The results show that the sum of SiO2, Al2O3 and Fe2O3 is equal to 77.95% which is greater than the minimum requirement of 70%. It is found that the compressive strength of the modified concrete decreases as the percentage cement replacement with VA increases from 5 to 30 %. Also, the early age (7 and 28 days) compressive strength of modified concrete of all replacement level are significantly lower than the plain concrete. It is also found*

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that the pozzolanic activity index (PAI) of modified concrete of all replacement level decreases as the percentage cement replacement with VA increases. Moreover, at 20% cement replacement with VA, 7 days curing gave PAI of 83.44% while 28 days curing gave PAI of 85.24%; both of which are greater than the minimum requirement of 75%. Therefore, the study concluded that based on the higher sum of acidic oxide (SiO2 + Al2O3 + Fe2O3) and PAI values than that which is prescribed in ASTM C 618 for Class N pozzolana, qualified the material suitable as a pozzolana.

Keywords: *Volcanic Ash, Cement, Concrete, Acid oxides, Pozzolanic activity index.*

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I. Introduction

Concrete production utilizes cement as its major ingredient. Cement production is an important consumer of natural resources and energy. Furthermore, the cement industry is a significant carbon dioxide (CO_2) producer (Suvash, et al., 2019). One of the ways to compensate for high energy consumption and CO_2 emission from the production of cement, thus making the utilization of concrete more sustainable, is the addition of mineral waste that can be used as a reactive component in the cement. Thus, the amount of cement is decreased and the waste is used instead of land-fill, (Ylmen, 2013). In addition, in recent years, due to the carbon footprint of cement, the utilization of environmentally friendly materials like ash has been on the rise. According to previous research results, ash is an amorphous material known for its high composition of aluminosilicates (Al-Si-Fe), which satisfies the design standard conditions (BS 8615-1, 2019; ASTM C618, 1978; AASHTO, 1993). Matawal (2005), highlighted the benefits of the application of use of various ashes as potential replacement of cement in mortar and concrete production, which include to: reduce or totally eliminate the classification of ashes as waste materials polluting the environment, and reduce the quantity and consequently the cost of cement applied in concrete works. The ashes from the locally available waste materials which can substitute cement in mortar and concrete are called pozzolana, which according to ASTM 618-94a describes as a siliceous or siliceous and aluminous material which, in itself, possesses little or no cementitious value but which will, in finely divided form in the presence of moisture, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. Pozzolans are of increasing interest because their use reduces overall negative environmental impact and degradation as well as cost when mixed with Portland cement in blended cement systems. The use of pozzolans reduces the carbon dioxide emitted per ton of product and can also improve various physical properties of the resulting concrete (Malhotra, 1996). In addition, it is known that the use of pozzolanic and cementitious materials in large quantities is very important to ensure that the cement and concrete industries are sustainable, not only in terms of energy efficiency and environment considerations, but also with respect to the durability and life-cycle cost of the resulting concrete structures (ACI Committee., 1988; Binici & Aksogan, 2006). Pozzolans are supplementary cementitious materials SCM, (Thomas, 2013); and the addition of it reduces the amount of cement in mortar and concrete production (Duggal, 2008; Peter et al, 2012), thus lowering cost of structures (Matawal, 2005). In addition, the uniqueness of pozzolana is that strength development
during use is slow and not as rapid as in Ordinary Portland Cement (OPC), though the desired strength attained in both cases in the later age are comparable (Matawal, et al., 2014). The effectiveness of these

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materials as cement replacements depends on their physical and chemical attributes and also on their origin (NRMCA 2012; Miller et al. 2016). The capacity of an ash or powder material for replacing Portland cement partly depends on its pozzolanic activity and, in turn, is related to the quantity of silica reactive and the amorphous phases present in the ash (Habert, 2008; and also, the fineness of the ash (Kaffayatullah et al., 2019). Ahmed et al., (2020), have mentioned that the contemporary research has established that the materials having around 70% pozzolanic ingredients like silicate/ aluminates/ oxides of certain metals exhibit an improved tendency to react with excess Ca $(OH)_2$ found in concrete during hydration process to form increased quantity of C-S-H gel which is responsible for binding/ strength of concrete. In initial hydration phase of cement concrete, tricalcium silicate and dicalcium silicate react with water to produce calcium silicate hydrate gel and calcium hydroxide. The pozzolanic materials which contain sufficient silicon dioxide but lacks in calcium react with excess calcium hydroxide produced during hydration phase of cement and further produce calcium silicate hydrate gel which improves the strength of pozzolanic composite. Studies on pozzolana have shown more insight on the benefit of pozzolana-cement in construction. According to Matawal, (2005), reported that the improved behaviour is a function of the activity of the addition and this varies from one pozzolana to another. In an effort by researchers to reduce the energy consumption and no CO_2 emission in cement production and hence, the production of sustainable concrete which required the blending of cement with the pozzolana is limited in Plateau state. Therefore, pozzolanic materials need to be extensively study in Plateau state couple with the abundance deposit of natural volcanic waste materials. Volcanic ash, referred to as "original pozzolan" or ''natural pozzolan'', is a finely fragmented magma or pulverized volcanic rock, measuring less than

2mm in diameter, which is emptied from the vent of a volcano in either a molten or solid state (Olawuyi, e al., 2012). Natural pozzolans have the potential to influence several properties in Portland cement concrete mixing and curing. The factors most significantly affected by natural pozzolans are water demand, set time, heat of hydration, and strength. The water content in a mix may also have influences on other properties such as workability and heat of hydration. When it comes to natural pozzolans, the effect they have on water demand for a given mix depends on the type. calcined clays and calcined shales generally have little effect on water demand in lower dosages; however, other natural pozzolans such as volcanic ash can significantly increase or decrease water demand. As a general rule, SCMs increase the setting time of Portland cement concrete. For most fly ash, calcined material and other natural pozzolans, the amount of additional set time is also directly proportional to the ratios of cement to SCM in the mix. Commonly, natural pozzolans lower the heat of hydration in a given hydration reaction. The majority of supplementary cementing materials (fly ash, natural pozzolans typically have a lower heat of hydration than Portland cement. Strength increase in regard to natural pozzolans can be likened to any chemical reaction, it all depends on the quantities, ratios, and inherent qualities of the reactants. If a mix has too much pozzolan and not enough cement, it is going to have less strength than a pure cement mix. Depending on the exact composition and physical properties of a given natural pozzolan, the time to control strength can range from one day for some slag cements and up to 90 days for more common natural pozzolans (Kosmatka et al., 2013). Campbell et al., (1982) showed that replacing 20% cement portion of the concrete mix with volcanic ash from the 1980 Mt. St. Helens eruption and found that it decreased the 28-day strength of the samples by over 40%. The trends shown by the Campbell study were corroborated in 2006 by Hossain and Lachemi when they also replaced 20% of the cement portion

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of a mix with volcanic ash. The Hossain study found that replacing these portions reduced the compressive strength of samples by 16%. According to ASTM C 618, Class N pozzolans are known as natural pozzolans. The most common class N materials include calcined clay, shales, or volcanic ash. The chemical and physical requirements of ASTM C-618 for the classification of Class N are SiO_2 + Al_2O_3 + Fe_2O_3 must be greater than 70%, SO_3 not more 4%, Strength activity index seven days of control or 28 days of control must be greater than 75%. Deposits of VA materials extend over approximately 0.84% of the world's land surface or 124 million hectares, of which 60% are distributed in tropical regions (Robayo-Salazar et al 2017). These deposits are easily accessible, can be naturally mined and have a better cost–benefit ratio compared with the traditional quarrying method commonly used for clay mining. Additionally, in densely populated countries with high economic growth, these deposits can have a significant commercial value for the cement industry because the VA can be used in the production of blended cement (Pourkhorshidi et al 2010). Volcanic materials are obtained from Andisols exclusively found in regions with past or present volcanism (Lemougna et al, 2018; Robayo-Salazar et al, 2018; Takahashi and Shoji, 2002; Najimi et al, 2018). The Jos Plateau lies precisely within the North Central Basement Complex of Nigeria. The Basement Complex rocks of the lower Palaeozoic to Precambrian ages underlie about half of its entire landmass. These rocks are represented by gneissmigmatites and intrusive into these Basement rocks are the Pan-African granites and the predominant Jurassic non-organic alkaline Younger Granites (Turner, 1976). Tertiary and Quaternary basaltic volcanoes are the youngest rocks in the area and overlie directly in the basement and in places of the Younger Granites (Wright, 1970). Two main basalt subtypes have been distinguished based on these periods of replacement and textural differences. They are the Older (Tertiary) and the Newer (Quaternary) basalts. The Newer basalts occupy nearly 150 km in the western and southern Jos Plateau. They also extend towards the Kafanchan area and Southwards down to the Shemankar valley. They occur as cones and lava flow characterized sleep-sided central craters rising a few meters above their surroundings. The Newer Basaltic cones are aligned in NNW-NNE direction, corresponding to the trend of dolerite dykes (MacLeod et al., 1971). From previous investigation carried out to assess the pozzolanic nature of volcanic deposit of Jos Plateau, it was reported by Dadu et al (2015) that the sum of the oxides of silica, aluminum and iron are over 76% by weight in all the materials samples tested, and the Sulphur and calcium contents are found to be low with values of 2% and 0.28% respectively; also Dadu (2011), revealed that the compressive strengths tests of concretes with 15% partial replacements of the PC with the pozzolan indicated that the Portland Pozzolana Cement concrete mixtures gave Pozzolanic Activity Index varying from 90 to 99%. Maton et al (2021), have reported that the oxide composition of VA obtained from Pidong has high content of; SiO_2 (44.16%), Al_2O_3 (22.96%), Fe_2O_3 (16.39%) and CaO (10.27%), total sum of SiO_2, Al_2O_3 and Fe_2O_3 equal to 83.51%. Agboola et al, (2020), have revealed that volcanic ash obtained from Kerang has combined sum of SiO_2, Al_2O_3 and Fe_2O_3 equal to 74.8%. Olawuyi (2010), revealed that the two samples of volcanic ash (VA) collected from different locations in Kerang, the sum of their oxides of silica, aluminum and iron were 63.74 and 67.14% respectively. Olawuyi et al (online), have reported that the volcanic ash obtained from Dutsin Dushowa has total Silicon Dioxide, Iron Oxide, and Aluminum Oxide (SiO_2+Fe_2O_3+Al_2O_3) content equal to 70.99%. The chemical assessment of volcanic deposit found around volcanic pond (Maton et al., 2021) where volcanic eruptions took place many years ago along Bokkos/Mangu Road at Pidong gave the highest combined sum of SiO_2, Al_2O_3 and Fe_2O_3 but its pozzolanic activity index was

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not assessed. Therefore, this study is to investigate the pozzolanic potential of volcanic ash sourced from Pidong along Bokko/Mangu Road.

II. Materials and Methods A. Materials

The materials used in the production of the concrete include Ordinary Portland Cement (OPC), fine aggregate, coarse aggregate, volcanic ash (VA) and water.

Cement

The brand of Dangote Portland cement Grade 42.5N was procured from a reputable supplier and used in this study. In conformity to ordinary Portland cement as specified in Bs 12:1978, the following tests were carried out on the cement: consistency and setting time of cement (plate 1) and the results is presented on table 1.

Plate 1. Performing consistency /setting time test

Plate 2. volcanic ash before sieving

Volcanic Ash

The volcanic materials were collected at Pidong, along Bokkos/Mangu Road of Plateau State, Nigeria. They are solid rocky materials found in abundance around the volcanic pond in the locality. The rocks were pulverized using a crushing machine of NBRRI Pozzolana/artisan and Skill acquisition training center Bokkos, Plateau State and sieved through BS sieve No. 200 (75µm) in NBRRI North Central Zonal Office's Laboratory Jos, Plateau State (plate 2, 3 and 4). The chemical oxide composition of volcanic ash was determined by means of X-ray florescence spectrometer test (XRSF). The sample analyses were performed at Research Laboratory of the Department of Chemical Engineering, Ahmadu Bello University Zaria, Kaduna state Nigeria and the results is presented on table 2.

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Plate 3. Sieving of volcanic ash Plate 4. volcanic ash after sieving

Aggregate

The aggregate (fine and coarse) was procured from a reputable supplier and used in this study. In conformity to aggregate as specified in Bs 812: part 2: 1975, the particle size distribution (using sieve analysis) was carried out on the aggregate and the results are presented on table 2.

Water

Pipe borne water fit for drinking was used throughout the study for mixing the concrete materials.

B. Method Production of concrete cubes

Mix ratio of 1:2:4 and 0.6 water cement ratio (w/c) were used for the production of the test concrete cubes. Twenty-one concrete specimens, each for 7- and 28-days curing, were produced with three test cubes for control specimens and three each for cement replacement of 5%, 10%, 15%, 20%, 25% and 30% respectively. The concrete specimens were produced by mixing the required weight of cement, volcanic ash, aggregate and water, after which it was poured into an oiled mold of size 150mmx150mmx150mm and compacted in three layers of 50mm each by ramming using steel rod, after which they were vibrated using vibrating machine of Building Department of University of Jos. The test cubes were demolded after 24 hours, weight and immersed in a curing tank filled with water for 7 and 28days at room temperature. After 7 and 28 days the test cubes were removed, weight and air dried. Test cubes were made from fresh concrete in compliance with BS 1881-108:1983.

Compressive strength of cube specimens

Failure load was obtained by crushing the test cubes using the compression machine in the Building Laboratory of the Department of Building, University of Jos, Plateau State. Compressive strength is determined using equation 1.

$Compressive\ strength = \frac{failure\ of\ specimen\ load (N)}{Area\ (mm^2)}$ --------------------------------------- (1)

III. Results and Discussion

The results are presented in Table 1 to 6 and figure 1 to 4, which are discuss below: Table 1.0 Results of Consistency and Setting Time of OPC and OPC-VA Paste.

% Replacement By weight	OPC (g)	VA (g)	Normal Consistency (%)	Initial Setting Time (Min)	Final Setting Time (Min)

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0VA	300	0	28.2	176	218
5VA	285	15	28.9	168	222
10VA	270	30	29.5	146	228
15VA	255	45	30.1	141	230
20VA	240	60	31.1	137	233
25VA	225	75	32.3	135	245
30VA	210	90	34.5	131	268

From Table 1 and figure 1 the results show that the consistency of the blended cement paste increases with the increase in percentage cement replacement by VA from 5 – 30%. The increased in the consistency of the OPC-VA paste may be attributed to a progressive water demand as the percentage replacement of cement increases. As mentioned by Kosmatka et al., (2003), that natural pozzolans such as volcanic ash can significantly increase or decrease water demand. In the present study, the water demand increases as percentage replacement of cement increases. According to Imene et al., (2019), they mention that increase in consistency of a cement blended with pozzolana can be explained by the effect of the absorption of mixing water by the pozzolan because of its porous structure. Table 1 and figure 2 also show that the initial setting time of OPC-VA paste decreases and the final setting time of OPC-VA paste increases as the percentage cement replacement by VA increases from 5 – 30 %. The decreased in initial and increase final setting time of OPC-VA paste may not be unconnected to the reduction of heat of hydration of the cement paste. As a result, there is increase in the setting time of OPC-VA paste as the percentage cement replacement increases. As mentioned by Kosmatka et al., (2003), that as a general rule, SCMs increase the setting time of Portland cement concrete; and for most fly ash, calcined material and other natural pozzolans, the amount of additional set time is also directly proportional to the ratios of cement to SCM in the mix.

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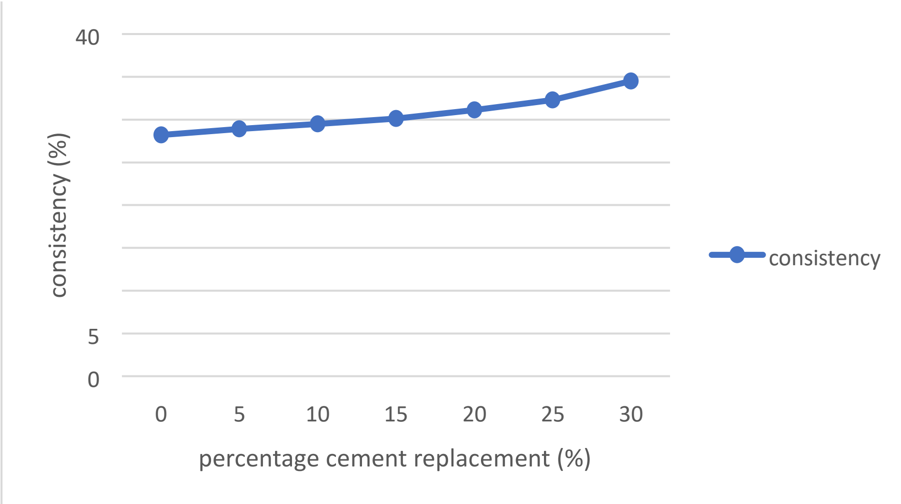

Figure 1. variation of consistency with percentage cement replacement

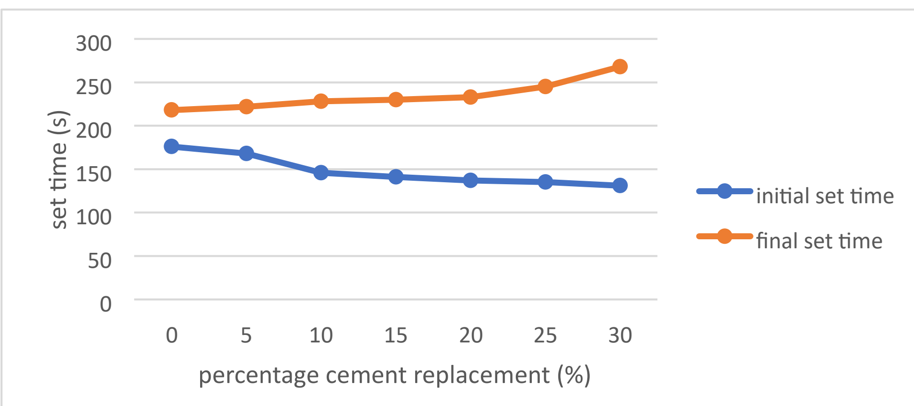

Figure 2. variation of set times with percentage cement replacement

Table 2. Results of Chemical and Physical Properties of VA

Constituents	Concentration by weight (%)

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SiO_2	40.457
FeO_3	21.885
Al_2O_3	15.612
MnO	0.365
SO_3	0.087
CaO	14.466
MgO	0.000
K_2O	1.227
TiO_2	3.803
ZnO	0.023
Cl	0.535
CuO	0.044
NiO	0.075
Bulk Density (Kg/m^3)	1490
$SiO_2 + Al_2O_3 + Fe_2O_3$	77.95

Table 2. shows the chemical composition of volcanic ash (VA) and the results show that the combined percentages of silica (SiO_2), Alumina (Al_2O_3) and ferrous oxide (Fe_2O_3) of the VA is 77.95%, which is higher than the minimum requirement of 70% which is prescribed in ASTM C 618 for Class N pozzolana. Few studies from Bokkos-Mangu road have reported varied oxide composition of VA, Maton et al (2021), have reported that the oxide composition of VA obtained from Pidong has the total sum of SiO_2, Al_2O_3 and Fe_2O_3 equal to 83.51%; Agboola et al, (2020), have reported that volcanic ash obtained from Kerang has combined sum of SiO_2, Al_2O_3 and Fe_2O_3 equal to 74.8%; Olawuyi (2010), reported the sum of oxides of silica, aluminum and iron equal to 63.74 and 67.14% respectively obtained from two different location at Kerang; and Olawuyi et al (online), have reported that the volcanic ash obtained from Dutsin Dushowa has total sum of Silicon Dioxide, Iron Oxide, and Aluminum Oxide ($SiO_2+Fe_2O_3+Al_2O_3$) content equal to 70.99%. From the previous studies, it has revealed that the VA from Pidong has the highest sum of SiO_2, Al_2O_3 and Fe_2O_3 equal to 83.51%, even higher than the sum of SiO_2, Al_2O_3 and Fe_2O_3 in the present studies which is equal to 77.95%.The different in the sum of SiO_2, Al_2O_3 and Fe_2O_3 in the present studies and that obtained by Maton et al (2021) from Pidong, may be attributed to the fact that they were obtained from different location. This agree with report by Olawuyi (2010), which revealed that samples from the same area but different location may differ in their sum of SiO_2, Al_2O_3 and Fe_2O_3 respectively. Sulphur trioxide (SO_3) of 0.087% in the present studies is much lower than the upper limit of 4% of the ASTM C 618 standard. The results of the chemical

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analysis of the VA suggest that the sample meets the chemical requirements for a class N natural pozzolan, indicating their potentiality for pozzolanic reactivity.

Table 3. Results of Sieve Analysis of Sand

Sieve Size	Weight Retained (g)	% Retained	% Passing
5mm	-	-	100.00
2.36mm	252	12.60	87.40
1.70mm	171	8.55	78.85
1.18mm	210	10.50	68.35
600µm	755	37.75	30.60
300µm	425	21.15	9.35
150µm	146	7.30	2.05
75µm	26	1.30	0.75
Receiver	15	0.75	0.00

Table 4. Results of Sieve Analysis of Gravel

Sieve Size	Weight Retained (g)	% Retained	% Passing
20mm	-	-	100.00
14mm	8	0.8	99.20
10mm	845	84.5	14.70
6.3mm	88	8.8	5.90
4mm	40	4.0	1.90
75µm	15	1.5	0.40
Receiver	4	0.4	0.00

From Table 3 and figure 3 The coefficient of uniformity (C_u) is equal to 2 and the coefficient of curvature (C_c) is equal to 1.3. Based on the Unified Soil Classification System (USCS), the C_c met the requirement for well graded sand which fall between 1-3 but C_u failed to satisfy the requirement for well graded gravel which must be greater than 6. Table 3 and 4, shows that less than 5% fines pass No. 200 sieve. Therefore, according to USCS the soil is classified as both poorly graded sand and gravel (SP and GP). It is found that this aggregate to be used in concrete, will be missing fine material which may introduced

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bleeding; but as stated in ACI 211.2-98 (1998), the aggregates used in concrete are generally missing the very fine materials, and the finely divided pozzolanic material mainly passing a No. 200 sieve (75 µm), can fill the missing fines in the aggregate mix, making the concrete denser, which can minimize the bleeding and segregation and give increased strength to the concrete.

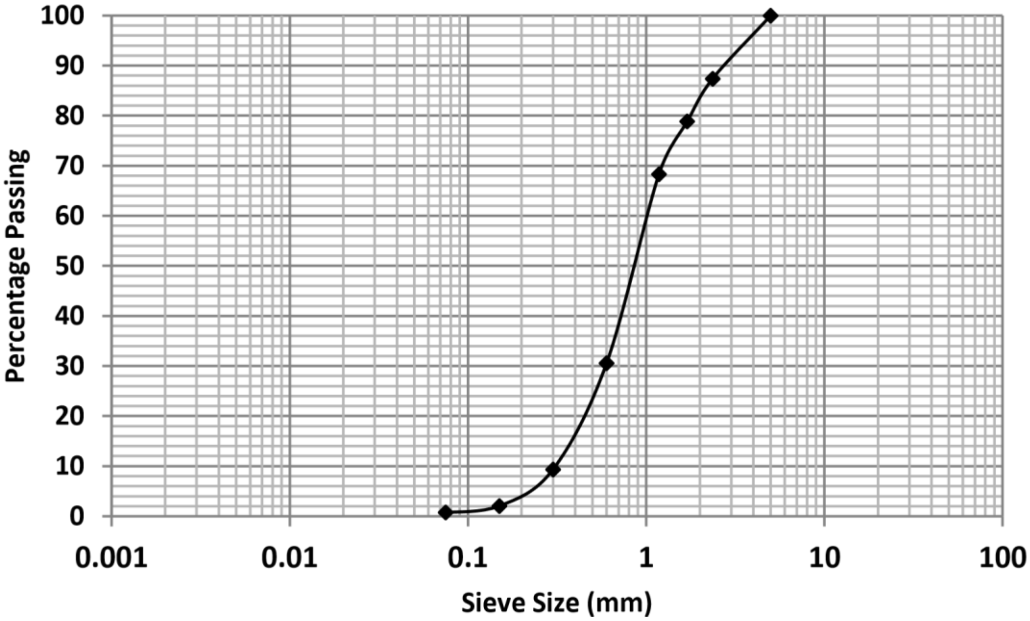

Figure 3. Particle size distribution of sand

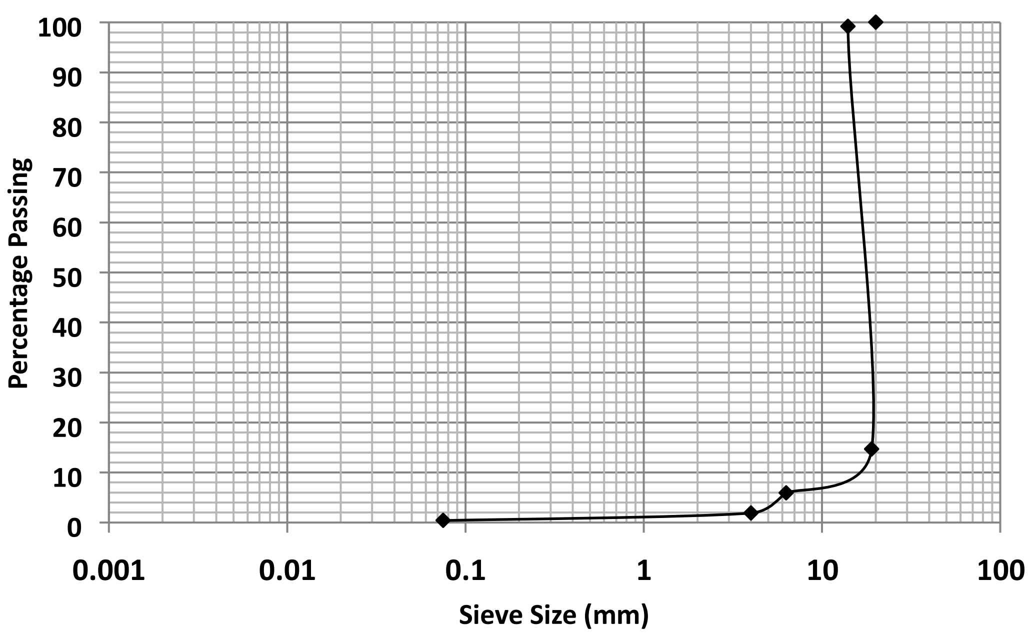

Figure 4. Particle size distribution of gravel

Table 5. Results of Compressive Strength of Plain and Modified Concrete for 7 and 28days Curing

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Percentage Replacement By Weight (kg)	0V	5V	10V	15V	20V	25V	30V
Compressive Strength for 7 days curing (N/mm^2)	24.15	22.09	21.70	20.22	20.15	19.69	15.11
Compressive Strength for 28 days curing (N/mm^2)	26.36	24.36	23.98	22.97	22.47	20.67	18.58

From Table 5 and figure 5 the results show that there is decrease in compressive strength of cube specimens for both the 7 and 28 days curing with the increase in percentage replacement of cement by the VA. This result agrees with the results reported by Nili and Salehi (2010). The decrease in compressive strength may not be unconnected to high water demand and reduction in heat of hydration. At each cement replacement with VA, and between 7 and 28 days curing there is increase in compressive strength. The increase in strength may be attributed to the addition of calcium silicate hydrates (C-S-H) and reduction of calcium hydroxides Ca $(OH)_2$). Ahmed et al., (2020), they have mentioned that the contemporary research has established that the materials having around 70% pozzolanic ingredients like silicate/ aluminates/ oxides of certain metals exhibit an improved tendency to react with excess Ca $(OH)_2$ found in concrete during hydration process to form increased quantity of C-S-H gel which is responsible for binding/ strength of concrete. It is also found that the early age (7 and
28 days) compressive strength of concrete with VA are significantly lower than the plain concrete. This result agrees with the results obtained by Kaid et al. (2015). Though according to Matawal, et al., (2014), the desired strength attained in both cases in the later age are comparable. As a result, according to Ahmed et al., (2019) there is usually long-term strength development up to and beyond 91 days in pozzolanic concrete; which according to Kamau and Ahmed (2017) can be up to 365 days.

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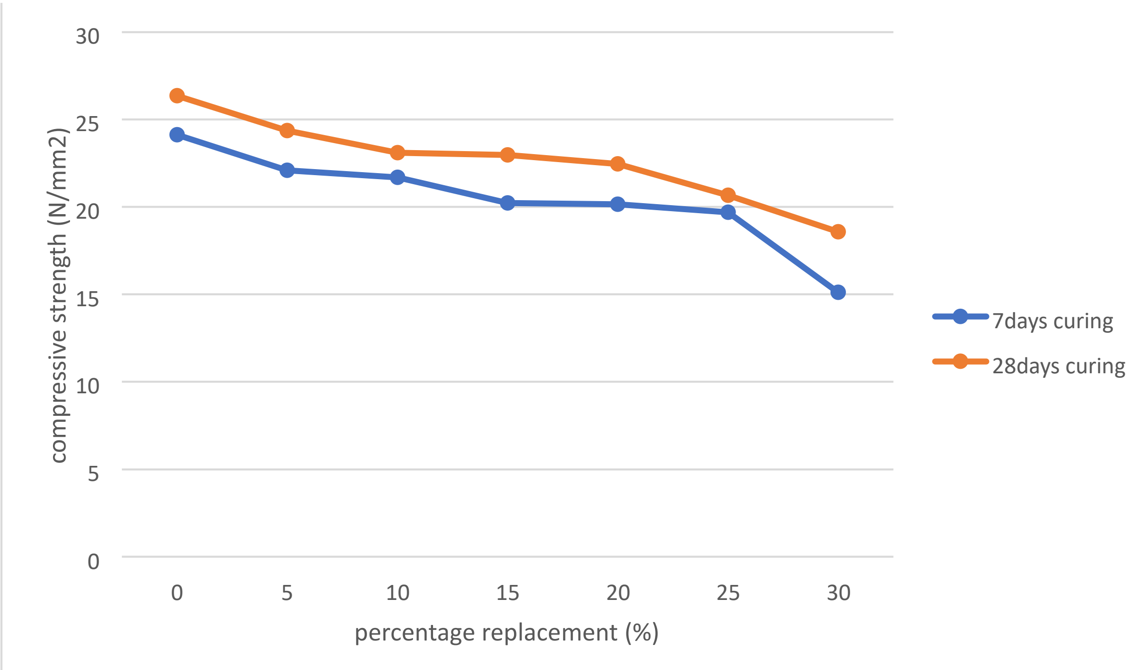

Figure 5. variation of compressive strength with percentage replacement

Table 6. Results of Pozzolanic Activity Index of Plain and Modified Concrete for 7 and 28days Curing

Percentage Replacement By Weight (kg)	0V	5V	10V	15V	20V	25V	30V
Pozzolanic Activity index for 7 days curing (%)	-	91.47	89.85	83.73	83.44	81.53	62.57
Pozzolanic Activity index for 28 days curing (%)	-	92.41	90.97	87.14	85.24	78.41	70.49

From Table 6 and figure 6 the results show that there is decrease in pozzolanic activity index (PAI) for 7 and 28 days curing with increase in percentage cement replacement by VA. At 20% replacement of cement by VA, the cube specimens for 7 and 28 days shows strength loss of
16.56% and 14.76% of the control specimen. The decreased in strength of 14.76% in the present study is lower than the decrease in strength of 16% and 40% reported by Hossain and Lachemi (2006 and Campbell et al., (1982), respectively. The PAI of 83.44 % and 85.24% for 7 and 28 days curing at 20% cement replacement are higher than 75% minimum requirement prescribed in ASTM C-618. This may be attributed to reactive silica in the VA which react with excess Ca $(OH)_2$ and produced additional C-S-H gel which is responsible for the strength in concrete; and may be the reactive silica that originates from explosive volcanic eruption and abrupt cooling during solidification. According to Mamoun (2004), as the generally accepted hypothesis the reactive glass originates from explosive volcanic

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eruption which prevents crystallization by abrupt cooling. The PAI of 7 and 28 days curing at 20% cement replacement have satisfied the minimum requirement of 75% as specified in ASTM C-618.

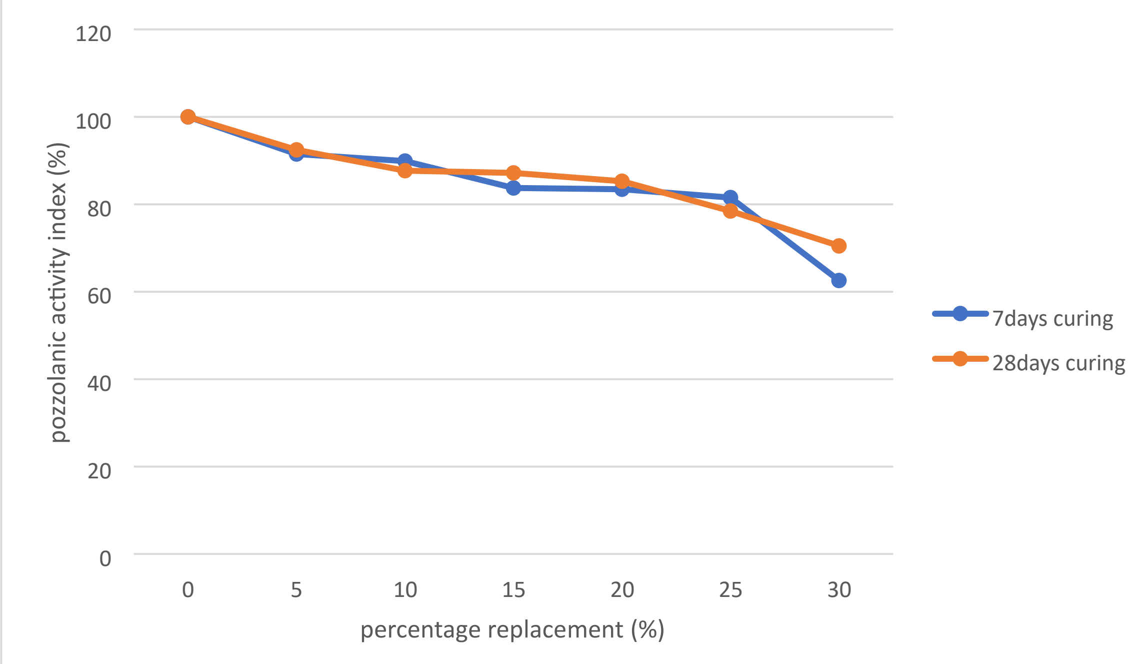

Figure 6. variation of pozzolanic activity index with percentage replacement

IV. Conclusion

Conclusions were drawn from this study as follows: The normal consistency of the OPC-VA paste increases as the percentage cement replacement with VA increases. Also, the initial setting time decreases as the percentage cement replacement with VA increases; this increases the set time of the blended cement. The sum of SiO_2, Al_2O_3 and Fe_2O_3 is equal to 77.95% which is greater than the minimum requirement of 70%. The compressive strength of the modified concrete decreases as the percentage cement replacement with VA increases from 5 to 30 %. Also, the early age (7 and 28 days) compressive strength of modified concrete of all replacement level are significantly lower than the plain concrete. Moreover, the PAI decreases as the percentage cement replacement with VA increases and at 20% cement replacement with VA, 7 days curing gave PAI of 83.44% while 28 days curing gave PAI of 85.24%; both of which are greater than the minimum requirement of 75%. Based on the chemical composition and PAI of the VA sourced from Pidong, it was found to be effective as a cement replacement and a pozzolanic material.

V. Recommendation

Recommendation is made from the study that more experiments should be done on VA obtained from Pidong to evaluate and analyzing more curing time greater than 28 days such as 56 and 91 days, and its effects on compressive strength

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