Quest Journals
Journal of Architecture and Civil Engineering
Volume 6 ~ Issue 3 (2021) pp: 28-34
www.questjournals.org

Research Paper

Evaluation for Mechanical Properties of Palm Oil Fuel Ash (POFA) Blended Granite - Gravel Concrete'

Hassan Laminu
Department of Civil Engineering maidriss Alooma polytechnic Geidam yobe state Nigeria

ABSTRACT
The study was carried out to establish an optimum replacement ratio of Palm Oil Fuel Ash (POFA) blended granite-gravel of concrete. Ordinary Portland Cement (OPC) concrete i.e. concrete with 100% OPC and ordinary gravel used as control, and concrete with 25% - 35% POFA replacement and granite-gravel of 0% - 100% replacement having uniform water/binder (w/b) ratios of 0.5 and mixes ration of 1:2:4 was utilized. Furthermore, curing ages of 7 days, 28 days, and 56 days were used. Thirteen runs of experiments were designed using the Central Composite Response Surface method (Design Expert). Based on the analyses, the optimum compressive strength of 26.59 N/mm^2 at %POFA of 26.69% and %Granite of 86.69% was observed. Also, the optimum strength found is slightly lower than the control (26.67 N/mm^2) with 0.30% difference. Furthermore, decrease in compressive strength due increase in %POFA was observed. Also Increase in Granite with increase of compressive strength was recorded. In addition, increase in concrete slump height was observed with increase in %POFA and %Granite.

KEYWORDS: *Concrete, Granite-Gravel, compressive strength, and Palm Oil,*

Received 29 Mar, 2021; Revised: 10 Apr, 2021; Accepted 12 Apr, 2021 © The author(s) 2021.
Published with open access at www.questjournals.org

I. INTRODUCTION

Concrete is regarded as the primary and widely used construction ingredient around the world in which cement is the key material. However, large scale cement production contributes greenhouse gases both directly through the production of CO_2 during manufacturing and also through the consumption of energy (combustion of fossil fuels). Currently world's annual cement production contributes about 7-8% of the global loading of carbon dioxide (CO_2) in to the atmosphere (Ridzuan, 2014). Moved by the economic and ecological concerns of cement, researchers have focused on finding a substitution of this over the last several years. In order to address both the concerns simultaneously many attempts have been made in past to use materials available as by product or waste. This is due to the fact that the use of by product not only eliminates the additional production cost, but also results in safety to the environment. Hence, the development and use of blended cement is growing rapidly in the construction industry mainly due to considerations of cost saving, energy saving, environmental protection and conservation of resources.

A number of investigations have been carried out with Palm oil fuel ash (POFA), an agro-waste ash, as potential replacement of cement in concrete. Sata et al. (2004) found compressive strength of 81.3, 85.9, and 79.8 MPa at the age of 28 days by using improved POFA with a reduced particle size of about 10 microns in concrete as replacement of 10%, 20% and 30% of cement respectively. They also reported highest strength at 20% replacement level. Tangchirapat [2009] observed the compressive strengths of ground POFA concrete in the range of 59.5–64.3 MPa at 28 days of water curing and with 20% replacement it was as high as 70 MPa at the end of 90 days of water curing. However, the drying shrinkage and water permeability were noted to be lower than that of control concrete with improved sulphate resistance. Past researchers also depict that both ground and un-ground POFA increase the water demand and thus decrease the workability of concrete. However, ground POFA has shown a good potential for improving the hardened properties and durability of concrete due to its satisfactory micro-filling ability and pozzolanic activity.

1.1 Physical properties

For the physical characteristics of POFA, it is easily affected by the operating system in the factory. Based on the previous studies, it is observed that the temperature of the incinerator that the industries controlled in the combustion of the palm oil wastes are between 800-1000°C and the duration of the operation is different. Furthermore, the physical properties of POFA are greyish in colour and it changes into darker colour as the result of the increase of the proportion of unburned carbon (Altwair et al., 2013; Noorvand, 2013; Aprianti et al., 2015). Drying shrinkage of POFA concrete has the same value as OPC concrete when 10% of OPC is replaced by POFA. However, the shrinkage increased slightly at 28 days because of the increasing of unground POFA percentage as a cement replacement (Khankhaje et al., 2016). Also, the water requirement for concrete with POFA is higher compared to normal concrete. So, the production of concrete with POFA will require more water (Khankhaje et al., 2016). The workability and density of the concrete also tends to decrease with the increase of POFA replacement (Awal, and Shehu, 2013; Ranjbar et al., 2014).

1.2 Chemical Properties of POPA

The amount of the unburned carbon causes the chemical constituents existing in POFA to vary. The range of the amount of the chemical composition present in the POFA is displayed in Table 2.1. In addition, Table 1.1.

Table 1.1: Chemical composition analysis in POFA

Chemical Composition (%)	Altwair et al. (2011)	Chindaprasirt & Rukzon (2009)	Jaturapitakkul et al. (2011)	Usman et al. (2014)	Usman et al. (2015)	Sata et al. (2010)
SiO_2	66.91	63.60	65.30	55.50	63.70	65.30
Al_2O_3	6.44	1.60	2.56	8.96	3.70	2.60
Fe_2O_3	5.72	1.40	1.98	3.25	6.30	2.00
CaO	5.56	7.60	6.42	8.81	6.00	6.40
MgO	3.13	3.90	3.08	2.45	4.10	3.10
Na2O	0.19	0.10	0.36	1.10	-	0.30
K_2O	5.20	6.90	5.72	7.81	9.15	5.70
SO_3	0.33	0.20	0.47	2.11	1.60	0.50
LOI	2.30	9.60	10.05	4.20	8.00	10.1

1.3 Mechanical properties of POFA

According to Khankhaje et al. (2016), the compressive strength of concrete decreases with the increase in percentage replacement of POFA and it depends on the finest of the POFA particles. However, for tensile strength, it shows an improvement where a specimen with 0.4 POFA/cement ratio has a tensile value of approximately 3.52 MPa. This value is 9% higher compared to control mix and 16% higher than a specimen with 1.2 POFA/cement ratio. For modulus of elasticity (MOE), the specimen mixed with POFA either fine or coarse is in range of 25.0 to 28.0 GPa. The value is quite similar to OPC concrete which is found to be 27.5GPa (Khankhaje et al., 2016). However, after POFA replaced cement by 50%, the compressive and tensile strength drop and recorded lower value than normal concrete (Khankhaje et al., 2016). Other than that, slow pozzolanic reactivity of POFA would decrease the early strength of concrete due to low C3S content that is only presence in cement (Momeen, et al., 2015).

II. RESEARCH METHODOLOGY

Ordinary Portland Cement (OPC) concrete i.e. concrete with 100% OPC and ordinary gravel as control, and concrete with 25% - 35% POFA replacement and granite-gravel of 0% - 100% replacement having uniform water/binder (w/b) ratios of 0.5 and mixes ration of 1:2:4 was used. Furthermore, curing ages of 7 days, 28 days, 56 days and 90 days were used. See table 3.1 for the mix design. Thirteen runs of experiments were designed using the Central Composite Response Surface method (Design Expert).

III. 3.0 RESULTS AND DISCUSSION

It was one of the most important test conducted on hard concrete with POFA Gravel-Granite replacement. The compressive strength tests were conducted on POFA Gravel-Granite concrete for different mixes ratio. The tests were conducted for 7, 28, 56 and 90 days under compressive strength testing machine. The results obtained were shown in the following tables

Table 3.1: Chemical Composition of POFA and OPC

S/N	*Chemical Nomenclature*	*Chemical Symbol*	% POFA	% OPC
1	Silicon oxide	SiO_2	59.15	17 - 25
2	Aluminium oxide	Al_2O_3	3.76	3.0 - 8.0

3	Iron oxide	Fe_2O_3	7.89	0.5 - 6.0
4	Calcium oxide	Ca_2O	13.45	60 - 67
5	Magnesium oxide	MgO	0.38	0.1 - 4.0
6	Potassium oxide	K_2O	3.69	1.17
7	Sulphur trioxide	SO_3	11.07	1.3 - 3.0
8	Manganese oxide	MnO	0.13	0.19

British standards specify amounts of Al_2O_3 in Portland cement within the range of 3.0% to 8.0%. So it can be observed that, POFA is within the specified limit. Similarly, amount of Magnesium oxide (MgO) qualified to fall within the range of specified British standards However, Iron oxide (Fe_2O_3) is slightly deviated from the specification range as shown in table 3.1. Furthermore, Potassium oxide (K_2O), and Sulphur trioxide (SO_3) are above the specified British Standard. Also, Calcium oxide (Ca_2O) and Manganese oxide (MnO) are below the required standard as specified by BS EN 197-1 and ASTM C150 Type I.

Table 3.2: Compressive Strength for 7 Days Curing Age

S/N	% POFA	% Granite Gravel	% OPC	Average Workability (mm)	Average Density (Kg/m^3)	Average Compressive Strength (N/mm^2)
1	0	0	100	72	2519	21.56
2	30	50	70	92	2655	19.78
3	35	0	65	98	2756	13.60
4	30	50	70	92	2655	19.78
5	27.5	50	72.5	84	2815	20.22
6	25	100	75	81	2607	20.44
7	30	75	70	86	2696	17.82
8	30	50	70	92	2655	19.78
9	30	50	70	92	2655	19.78
10	25	0	75	77	2696	15.60
11	30	50	70	92	2655	19.78
12	35	100	65	97	2637	20.09
13	30	25	70	84	2519	18.22
14	32.5	50	67.5	86	2726	17.24

Higher compressive strength of $20.44N/mm^2$ was observed at 25% POFA, 100% Gravel–Granite and 75% OPC for curing age of 7 days

Table 3.3: Compressive Strength for 28 Days Curing Age

S/N	% POFA	% Granite Gravel	% OPC	Average Workability (mm)	Average Density (Kg/m^3)	Average Compressive Strength (N/mm^2)
1	0	0	100	72	2667	24.44
2	30	50	70	92	3255	24.63
3	35	0	65	98	2785	19.24
4	30	50	70	92	3255	24.63
5	27.5	50	72.5	84	2874	25.33
6	25	100	75	81	2661	25.56
7	30	75	70	86	2756	23.11
8	30	50	70	92	3255	24.63
9	30	50	70	92	3255	24.63
10	25	0	75	77	2785	20.44
11	30	50	70	92	3255	24.63

12	35	100	65	97	2726	24.84
13	30	25	70	84	2667	23.56
14	32.5	50	67.5	86	2716	22.31

Higher compressive strength of 25.56N/mm^2 was also observed at 25% POFA, 100 Gravel–Granite and 75% OPC for curing age of 28 days.

Table 3.4: Compressive Strength for 56 Days Curing Age

S/N	% POFA	% Granite Gravel	% OPC	Average Workability (mm)	Average Density (Kg/m^3)	Average Compressive Strength (N/mm^2)
1	0	0	100	72	2637	26.67
2	30	50	70	92	2649	26.07
3	35	0	65	98	2726	20.89
4	30	50	70	92	2649	26.07
5	27.5	50	72.5	84	2705	25.82
6	25	100	75	81	2661	26.18
7	30	75	70	86	2667	23.11
8	30	50	70	92	2649	26.07
9	30	50	70	92	2649	26.07
10	25	0	75	77	2756	22.13
11	30	50	70	92	2649	26.07
12	35	100	65	97	2726	26.13
13	30	25	70	84	2637	24.27
14	32.5	50	67.5	86	2696	21.02

Higher compressive strength of 26.18N/mm^2 was recorded at 25% POFA, 100 Gravel–Granite and 75% OPC for curing age of 56 days.

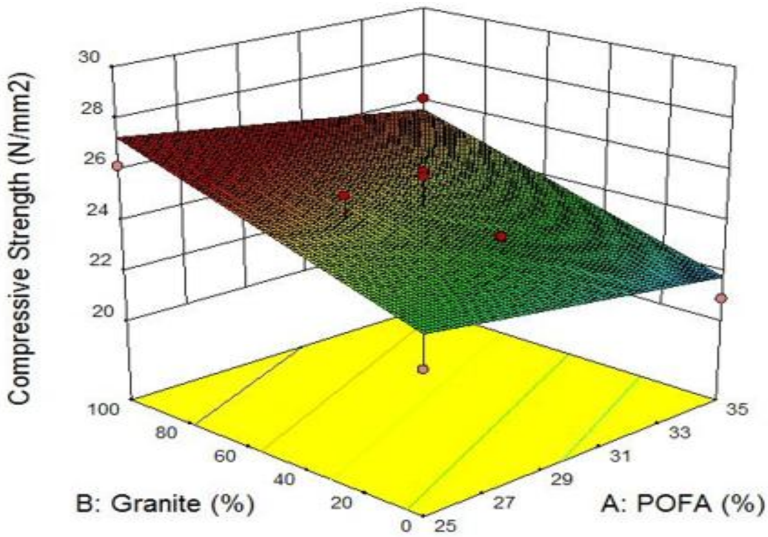


Figure 3.1: Compressive Strength Vs Granite and POFA

Figure 3.1 shows effect of granite and POFA mix ratio on compressive strength of concrete. Increase in granite volume lead to increase in compressive strength. However, increase in POFA percentage decrease in compressive strength.

Table 3.4: Analysis of variance between %Granite and %POFA with respect to compressive Strength

Analysis of variance table [Partial sum of squares - Type III]						
Source	**Sum of Squares**	**df**	**Mean Square**	**F Value**	**p-value Prob > F**	
Model	324.44	2	162.22	10.28	0.0038	significant
A-POFA	*320.89*	*1*	*320.89*	*20.33*	*0.0011*	
B-Granite	*3.56*	*1*	*3.56*	*0.23*	*0.6453*	
Residual	157.86	10	15.79			
Lack of Fit	*147.06*	*6*	*24.51*	*9.08*	*0.0256*	*significant*
Pure Error	*10.80*	*4*	*2.70*			
Cor Total	482.31	12				

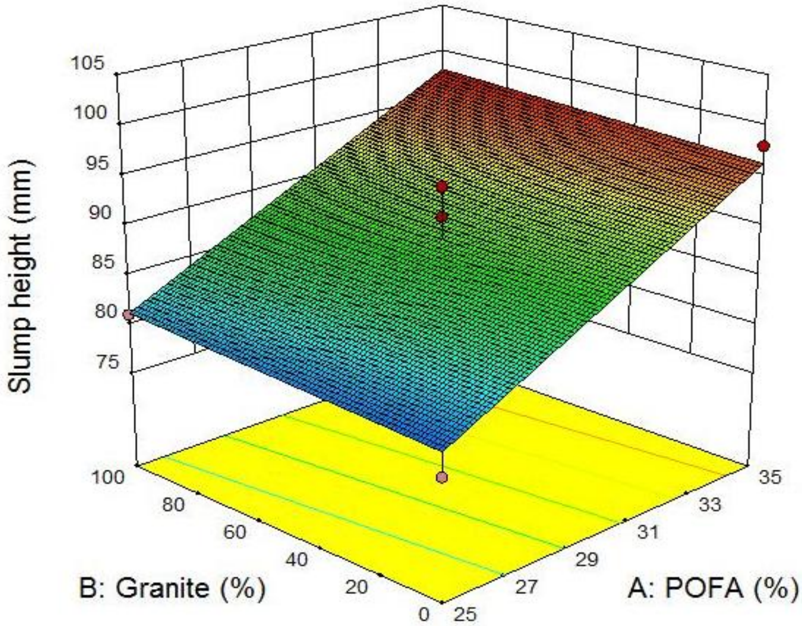
The difference is significant

Therefore, concrete compressive strengths are not the same under the percentage POFA replacement of 25% - 35% and Granite 0% - 100%. This is due to the significance difference ANOVA analysis established. Also, R – squared shows 0.67 or 67% relationship between %POFA and %Granite with respect to compressive strength.

Table 4.6 Regression analysis for 56 days age concrete

Concrete	*Regression Coefficients*	*Values*	*Standard Error*
% POFA	A_1	0.00	0.00
% Granite	A_2	0.03	0.01
%OPC	A_3	0.20	0.09
Workability	A_4	0.14	0.09
Density	A_5	-0.02	0.01

According to the analysis, the independent variable infuencing the compressive strength of the concrete is Ordinary Portland Cement (OPC) with the highest regression coefficient of 0.20, followed by workabilty with regression coefficient of 0.14 and followed by granite gravel with 0.03 coefficient.



s

Figure 3.2: Slump Height Vs Granite and POFA

Considering figure 3.2, granite and POFA have an influence on slump height of concrete. The higher the percentage of granite or POFA in concrete using 1:2:4 mix ratio, the higher the slump height.

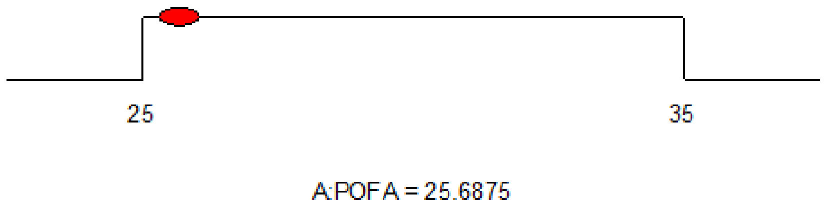


Figure 3.3: Optimum % POFA at 1:2:4 Mix Ratio

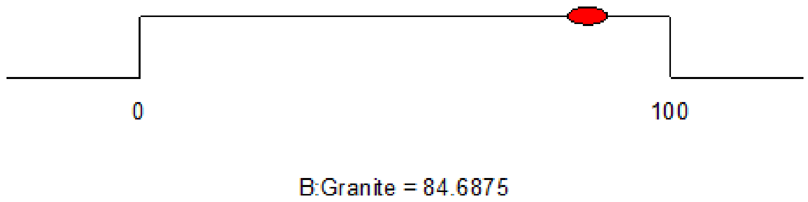


Figure 3.4: Optimum % Granite at 1:2:4 Mix Ratio

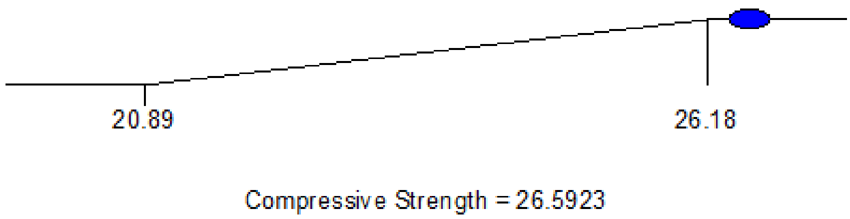


Figure 3.5: Compressive Strength at Optimum % Granite and %POFA at 1:2:4 Mix Ratio

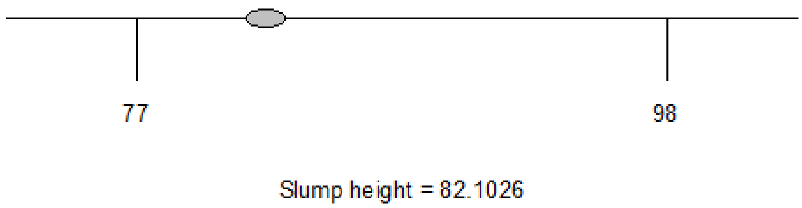


Figure 3.6: Slump Height at Optimum % Granite and %POFA at 1:2:4 Mix Ratio

Optimum mix ratio

The optimization analysis was carried out using Central Composite Response Surface method (Design Expert). The analysis shows that, at 25.69% POFA and 84.69% Granite, compressive strength of 26.59 N/mm^2 and slump height of 82.10mm was obtained. The optimum strength found is slightly lower than the control (26.67 N/mm^2) with 0.30% difference.

IV. CONCLUSION

The study established an optimum replacement of POFA from 0% - 35% and granite from 0 – 100% in order to produce an optimum concrete compressive strength at mix ratio of 1:2:4. Based on the analyses, the following conclusions were drawn:

1. Optimum compressive strength of 26.59 N/mm^2 at %POFA of 26.69% and %Granite of 86.69% was observed. The optimum strength found is slightly lower than the control (26.67 N/mm^2) with 0.30% difference.
2. POFA, OPC Gravel-Granite percentage replacement, density, workability and curing ages do not have equal effect on increase or decrease of compressive strength of a concrete. According to regression, %OPC is must sensitive variable influencing the compressive strength.

3. Decrease in compressive strength due increase in %POFA was observed. Also Increase in Granite with increase of compressive strength was recorded. Furthermore, increase of %POFA and %Granite increases slump height of concrete.
4. Oxides Composition analysis of POFA has been determined and the percentage amount of Al_2O_3 and MgO fall within the specified amounts of British Standard of Ordinary Portland Cement range 3.0% to 8.0% and %0.1 - 4.0% respectively. However, Fe_2O_3 is slightly deviated from the specification range. In addition, K_2O and SO_3 are above the specified British Standard. Also, Ca_2O and MnO are below the required standard as specified by BS EN 197-1 and ASTM C150 Type I.

REFERENCES AND BABLIOGRAPHY

[1]. Altwair, N.M., Johari, M.A.M. and Hashim, S.F.S., 2013. Influence of treated palm oil fuel ash on compressive properties and chloride resistance of engineered cementitious composites. Materials and Structures, 47(4), pp.667–682.

[2]. Aprianti, E., Shafigh, P., Bahri, S. and Farahani, J.N., 2015. Supplementary cementitious materials origin from agricultural wastes - A review. Construction and Building Materials, 74, pp.176–187.

[3]. Awal, A.S.M.A., and Shehu, I.A., (2013) "Evaluation of heat of hydration of concrete containing high volume palm oil fuel ash. Fuel", 105, 728-731

[4]. Altwair, N.M., Azmi, M., Johari, M. and Hashim, S.F.S., (2011). Strength Activity Index and Microstructural Characteristics of Treated Palm Oil Fuel Ash. International Journal of Civil & Environmental Engineering, 11(October), pp.85 – 92.

[5]. Chindaprasirt, P. and Rukzon, S., (2009). Pore Structure Changes of Blended Cement Pastes Containing Fly Ash, Rice Husk Ash, and Palm Oil Fuel Ash Caused by Carbonation. Journal of Materials in Civil Engineering, Vol. 21; N (November), pp.666–671.

[6]. Jaturapitakkul, C., Tangpagasit, J., Songmue, S. and Kiattikomol, K., (2011). Filler Effect And Pozzolanic Reaction Of Ground Palm Oil Fuel Ash. Construction and Building Materials, 25(11), pp.4287–4293.

[7]. Khankhaje, E., Hussin, M.W., Mirza, J., Rafieizonooz, M., Salim, M.R., Siong H.C., and Warid, M.N.M., (2016) "Blended cement and geopolymer concretes containing palm oil fuel ash. Materials and Design", 89, 385-398

[8]. Momeen M., Islam, U.l., Mo, K.H., Alengaram U.J., and Jumaat, M.Z., (2015) "Mechanical and fresh properties of sustainable oil palm shell lightweight concrete incorporating palm oil fuel ash", J. of Cleaner Production, 115, 307-314.

[9]. Noorvand, H, (2013). "Physical and Chemical Characteristics of Unground Palm Oil Fuel Ash Cement Mortars with Nano silica. Construction and Building Materials", 48, pp.1104–1113.

[10]. Ranjbar, N., Mehrali, M., Alengaram, U.J., and Metselaar, H.S.C., (2014) "Compressive strength and microstructural analysis of fly ash/palm oil fuel ash based geopolymer mortar under elevated temperatures". Construction and Building Materials, 65, 114-121

[11]. Sata., V., Jaturapitakkul., C., & Rattanashotinunt, C., (2010) "Compressive Strength and Heat Evolution of Concretes Containing Palm Oil Fuel Ash", Journal of Materials in Civil Engineering, Vol. 22, ©ASCE, ISSN 0899- 1561/2010/10-1033–1038.

[12]. Sata, V., Jaturapitakkul, C. and Kiattikomol, K., (2004). Utilization of Palm Oil Fuel Ash in High-Strength Concrete. Journal of Materials in Civil Engineering, 16(December), pp.623–628.

[13]. Usman, J., Zaky, M. and Arifin, Z., (2014). Effects Of Palm Oil Fuel Ash Composition On The Properties And Morphology Of Porcelain-Palm Oil Fuel Ash Composite. Jurnal Teknologi (Sciences & Engineering), 70(5), pp.5–10.