IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 22, Issue 2 Ser. 3 (Mar. – Apr. 2025), PP 39-44
www.iosrjournals.org

Approprating Plantain Peel And Plantain Leave Ash For Improved Cement Replacement In Concrete

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Abstract
The plantain extracts have been found to contain similar properties like ordinary Portland cement. This article is aim to provide improved cement replacement when a combination of both plantain leaf (PL) and plantain peel (PP) ash are combined as admixture. The PL and PP were burnt in an incinerator and the ash passed through sieve size 45um and concrete grade of 25N/mm^2 was used. The design mix of 1:1.8:2.7 with w/c of 0.5 was used to cast the concrete. The PL and PP ash was blended with cement at different level of replacement by weight, from 0%, 5%, 10% and 20% for cement paste and mortar. The setting time test carried out on the paste, indicates that increasing percentage replacement retards the setting time. The slump test shows that plasticity increases with increase replacement. Compressive strength test was carried out on all the different cubes on 7th, 14th, 21st and 28th days of curing. Result shows that, there was drop in strength at the initial stage, yet improved strength development was observed as curing days progresses. The normal crushing strength of 25N/mm^2 was reached by zero% - 10% replacement, while others dropped slightly. Mathematical model was used to analyze and predict the compressive strength at varying ages. The correlation of the result was carried out to ascertain the soundness of the result which gave a correlation of 0.97 showing that the combination of both, can be used for cement replacement up to 10%.

Keywords: *Plantain peel, plantain leaf ash**,** Cement-Replacement, Concrete, Compressive Strength.*

Date of Submission: 08-04-2025 Date of Acceptance: 18-04-2025

I. Introduction

Civil construction has defined standards that must be followed to avoid failure for both materials and technical application. The negative shift of our economy has made these construction materials such as cement unaffordable. This is forcing both producers and users to reduce the standard as we can observe in the steel industry. If this is not checked, it may lead to a disastrous end which include building collapsed. In order to arrest this present situation, this research was carried out. Many other research has been carried out to find out other replacement for cement in concrete. Researches show that many agricultural by products lying waste like groundnut shell, plantain leaf, bread fruits husk can serve as partial replacement to cement. (Mehta, 2006, and Mindendort et al, 2023). This research is one among many that is trying to find cheaper, quality and alternative means of reducing cost, especially, that of cement. Ugwu and Ugwuanyi (2020) studied on the use of plantain leaf alone as a concrete admixture, and came out with the result showing only 5% replacement for cement. While in similar research carried out to evaluate plantain peel as admixture by Omotosho(2017) indicates only 1% replacement by weight of cement and mainly serving as a retarding agent. The researches were seeking to determine the percentage replacement that can improve combination of Plantain Leaf Ash and Plantain Peel Ash as an admixture in concrete. The plantain leaf is always littering the ground in every plantain plantation. Its easily accessible and affordable. It doesn't decay easily like other leaves to form compost manure. Plantain peel on the other hand is a byproduct of plantain processing industry which are dumped to decay).

Olabanji et al (2012) conducted an analysis on the primary composition of plantain peel ash (PPA) with the view of using it as alkali for soap making. Research by Omotosho et al (2017) shows that PPA contain similar chemical composition to that of cement but reacts more as alkalin. The research noted that PPA is reach in calcium, potassium, iron and magnesium. While Ugwu and Ugwanyi (2020) found out that the plantain leaf ash (PLA) acts as a pozzolans. The pozzolans are siliceous and aluminous material. This is said to enhance the cement quality according to Padney et.al (2003). Pozzolans possess little or no cementitious value but which will, in finely divided form and in the presence of water, react chemically with calcium hydroxide (Ca (OH) at ordinary temperature to form compounds possessing cementitious properties (Mehta, 1987). Pozzolanic activity is given by the grading of it's ability to react with calcium hydroxide and water (Shah and Ahmed 2015). When compared to ordinary Portland cement, which consist majorly of lime (CaO), siilica, (SiO2), alumina (Al2O3) and iron oxide, magnesium oxide (MgO), TiO_2 Mn_2O_3, K_3O and Na_2O (Bensted 2008 and Hewlett 2013)

II. Materials And Methods

Plantain Peel And Leaf Ash

The ash of both plantain peel and leaf are gotten by burning and the by-product collected from industrial waste and plantain farms by fire under a temperature above 700^c to get the ash. It was then pass-through sieve of 45um according to ASTM C204 standard for cement to obtain the ash of 50-55% passing through. It is not as finer as ordinary Portland cement.

Ordinary Portland Cement of BS 12 was used as control.

Fine Aggregate with specific gravity of 2.67 and finess modulus of 2.250.

Crushed Coarse Aggregate with maximum aggregate size of 10mm well graded, and with specific gravity of 2.8

Potable Water was used for concreting and curing of samples. The water aided the hydration of cement which resulted in setting and hardening of the concrete according to (BS 3148)

Sample mix design

Free water content = 200kg/m³
Cement content = 200/0.5 = 400kg/m³
Relative density of aggregate = 2.7, Concrete density = 2400Kg/m³
Total aggregate content= 2400 - 200 - 400 = 1800kg/m³
GRADING: of fine aggregate (% passing 5mm) = 32 - 40%
Proportion of fine aggregate 40%
Fine aggregate content= 1800 * 0.40 = 720kg/m³
Coarse Aggregate content= 1800 - 720 = 1080kg/m³
MIX RATIO: 400/400; 720/400; 1080/400 = 1: 1.8: 2.7

Table 1: Mix proportion of materials.

Percentage (%)	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	PL and PP Ash (kg)	W/C
O	1.0	1.80	2.70	0.00	0.50
5	0.95	1.80	2.70	0.50	0.50
10	0.90	1.80	2.70	0.10	0.50
15	0.85	1.80	2.70	0.15	0.50
20	0.80	1.80	2.70	020	0.50

Test for Pozzolanicity: The specific gravity of (PP/LA) is 1.80, with fineness modulus of 1.35. Pozzolanicity sample test was carried out for the PP/LA. The test was done by mixing a weighed mass of the ash with a weighed volume of Calcium hydroxide solution [Ca (OH)2] of known concentration and titrating. when in contact with water, pozzolanic material can bind with calcium hydroxide, which is one of the ways to evaluate pozzolanic materials. This is by directly measuring the amount of calcium

Test on fresh Concrete

Slump test: This test is useful for finding the variations in the uniformity of a mix of given nominal proportions and specifies procedure for determining the consistency of concrete.

Setting time test on mortar: Vicat apparatus was used to obtain the initial and final setting of cement paste

Test on Hardened Concrete tests carried out on Hardened Concrete were Compressive Strength Test, at day 7, 14, 21 and 28, with cubes mould of 150mm * 150mm* 150mm.

Analysis of Data: Mathematical model was use to analyze and predict the compressive strength at varying ages. The correlation of the result was carried out to ascertain the soundness of the result

III. Results And Discussion

Mortar setting time was carried out at different percentages and the results is shown in Table 2

Table 2: Mortar setting time

Percentage (%}	Initial Setting time (min)	Final setting time (min)
0	50	518
5	58	582
10	60	590
1`5	68	615
20	70	630

Slump test: the result of the slump is displayed in Table 3 below

Table 3: Slump test

Percentage (%)	Slump (mm)
0	27.8
5	32
10	41.2
15	48.5
20	60.3

The relationship between the water absorption both of cement and that of PP/LA shows that it's more in cement than that of PP/LA and consequently, increase in the percentage replacement with cement, increases the amount of free water available for mixing, thereby increasing workability. it could be observed that at 5%, the plantain peel & leaf ash as admixture represents a standard workability for the concrete.

Pozzolana Test Result:

The Table 4 shows the outcome of the Pozzolanicity.

Time (min)	Titre value (mol/dm³)
30	0.250
60	O.220
90	0.150
120	0.101

Samples of the mixture against hydrochloric acid solution of known concentration with different time intervals in minutes; (30, 60, 90, 120) using phenolphthalein as indicator at normal temperature. The titre value reduced with time, confirming the ash as a Pozzolana that utilize more of the calcium hydroxide which decrease the alkalinity of the mixture.

Compressive test result of PP/LA

Table 5: Average Weight Result

Mix ratio (%)	Day 7	Day 14	Day 21	Day 28
0	8.406	8.554	8.412	8.398
5	8.522	8.763	8.689	8.631
10	8.114	8.210	8.010	8.016
15	7.998	8.060	7.914	7.988
20	7.864	7.954	8.010	7.892

Table 6: Average load (kN)

MIX RATIO (%)	Day 7	Day14	Day 21	Day 28
0	390.50	402.20	520.50	604.80
5	407.55	365.65	530.50	549.65
10	268.25	348.85	354.16	393.04
15	250.30	298.35	332.05	357.73
20	218.70	229.20	240.45	269.70

Table 7: Average Strength

Mix Ratio (%)	Day 7	Day 14	Day 21	Day 28
0	18.33	20.86	24.16	29.83
5	16.71	19.24	23.44	28.45
10	16.68	18.78	22.56	25.93
15	16.53	17.66	21.40	24.81
20	15.05	17.06	20.03	23.26

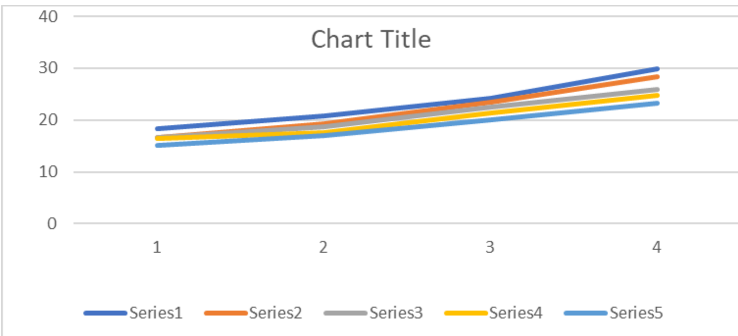

Figure 1: Average strength

The crushing load and compressive strengths of the control concrete and PLA and PPA replacements concrete are shown in tables 3.4 and 3.5 respectively. The results indicates that the compressive strength values of the control concrete increased steadily as the concrete ages. At 7 to 28 days, the concrete compressive strength increased from 18.33N/mm² to 29.83N/mm². The PLA and PPA replacement concrete compressive strength consistently decreases with increase in percentage replacement but a matchable strength is gotten at 5% - 10% replacement. The normal control mix gained strength faster initially, but the PLA concrete samples gained appreciable strength from the 7 to the 28 days age. The initial low strength gain of PP/LA concrete can be attributed to the low rate of pozzolanic reaction at those ages. The silica from pozzolans reacts with lime produced as by-product of hydration of OPC to form additional calcium-silicate-hydrate (C-S-H) that increases the binder efficiency and the corresponding strength values at later days of curing.

The variation in strength with age for the PLA and PPA concrete is different from that of the control as it continues to attain much higher strength as the concrete age increases. The PLA and PPA concrete compressive strength picks up more slowly up and stabilizes more at 28. Both the 5% and 10% replacement were able to reach the normal concrete strength of 25N/mmm by 28 days making it suitable for cement replacement.

Mathematical Model For Compressive Strength Of Cement-Pla Percentage Replacement

The mathematical model for predicting the compressive strength of concrete for cement-pp/pl ash percentage replacement as it ages is presented here. The Levenberge Marquardt and Guass Newton model was used for the prediction.

The compressive strength of cement (f-c) is modeled using a nonlinear regression equation $f_{\_c} = a \times (1 - b \times x^c) \times (1 + d \times t^e)$

Where f_c = compressive strength of cement (mpa)
X= percentage of admixture replacement (%)
a, b, c , d, e = e model coefficients.
t = hardening days.

Table 8: Result of compressive strength from model using levenberg marquardt algorithm

Percentage %	Day7	Day 14	Day 21	Day 28
0	18.31	20.85	24.14	29.81
5	16.69	19.22	23.42	28.43
10	16.66	18.76	22..54	25.91
15	16.51	17.64	21.38	24.79
20	15.03	17.04	20.01	23.24

A = 19.23, b = 0.123, c = 1.03, d = 0.08, e= 1.02

Table9: Comparison between the laboratory value and the predicted

Percentage %		Day 7	Day 14	Day 21	Day28
0%	Lab	18.33	20.86	24.16	29.83
	Model	18.31	20.85	24.14	29.81
5%	Lab	16.71	19.24	23.44	28.45
	Model	16.69	19.22	23.42	28.43
10%	Lab	16.68	18.78	22.56	25.93
	Model	16.66	18.76	22.54	25.91
15%	Lab	16.53	17.66	21.40	24.81
	Model	16.51	17.64	21.38	24.79
20%	Lab	15.05	17.06	20.03	23.26
	Model	15.03	17.04	20.01	23.24

The predicted values shows good agreement with the experimental values, indicating that the mathematical model is valid

Comparison of text result using Gauss

The mathematical model to describe the relationship between the compressive strength of cement (f.c) and the admixture replacement (x) and hardening days (t):
$f_c = a \times (1 - b \times x^c) \times (1 + d \times t^e)$

After several iteration, the algorithm converge to the following values: a = 19.41, b = 0.129, c = 1.02, d = 0.053, e = 1.01

Table10: Average compressive strength (n/mk2)

Percentage %	Day 7	Day 14	Day 21	Day 28
0	18.30	20.84	24.13	29.80

5%	16.69	19.21	23.41	28.42
10%	16.66	18.75	22.53	25.90
15%	16.51	17.63	21.37	24.78
20%	15.02	17.03	20.00	23.23

Table11: Compare the laboratory and the predicated.

Average compressive strength (n/mn2)					
	Description	**Day 7**	**Day 14**	**Day 21**	**Day 28**
0	Lab	18.33	20.86	24.16	29.83
	Model	18.30	20.84	24.13	29.80
5	Lab	16.71	19.24	23.44	28.45
	Model	16.69	19.21	23.41	28.42
10	Lab	16.68	18.78	22.56	25.93
	Model	16.66	18.75	22.53	25.90
15	Lab	16.53	17.66	21.40	24.81
	Model	16.51	17.63	21.37	24.78
20	Lab	15.05	17.06	20.03	23.26
	Model	15.02	17.03	20.00	23.23

The predicated values show good agreement with experiment values, indicating that the mathematical model is valid. Which also the sustainability of the pp/pl ash/ cement concrete for use.

Pair Wise Comparison

The result of the pair wise comparison results between zero percent other percentages for each paird

Table 12: Pair use comparison result for day 7

Pair wise comparison	Difference	Standard error	t-value	p- value
0.00 vs 0.05	1.62	0.23	7.04	<0.001
0.00 vs 0.10	1.65	0.25	7.17	<0.001
0.00 vs 0.15	1.80	0.23	7.83	<0.001
0.001 vs 0.020	3.28	0.23	14.26	<0.001

Table13: Pair use comparison result for day 14

Pair wise comparison	Difference	Stander error	t- value	p- value
0.00 vs 0.5	1.63	0.25	6.52	< 0.001
0.00 vs 0.10	2.09	0.25	8.36	<0.001
0.00 vs 0.15	3.12	0.25	12.84	<0.001
0.004 vs 0.20	3.81	0.25	15.24	<0.001

Table14: Pairwise comparison result for day 21

Pairwise comparison	Difference	Standard error	t- value	p- value
0.00 vs 0.05	0.72	0.27	2.67	<0.015
0.00 vs 0.10	1.80	0.27	5.93	<0.001
0.00 vs o.15	2.76	0.27	10.22	<0.001
0.00 vs 0.20	4. 13	0.27	15.30	<0.001

Table15: Pairwise comparison result for day 28

Pairwise comparison	Difference	Standard error	t- value	p-value
0.00 vs 0.05	0.38	0.11	2.05	<0.001
0.00 vs 0.10	0.78	0.11	2.45	<0.001
0.00 vs 0.15	1.06	0.11	3.64	<0.001
0.00 vs 0.20	2.06	0.11	5.82	<0.001

Nb = the d- value are on a significant level of a = 0.05.

The pairwise comparison result indicate that

For days, the comparison strength of concrete with % admixture replacement is signification higher than all other percentages ($p<0.001$).

The compressive strength decreases as the admixture percentage increases.

$1 < tv < 3$ showing the imaginary difference between control and 10% replacement which helps to accept up 10% replacement for the admixture.

Anova Test

Null hypothesis (Ho): the mean compressive strength of cement with different admixture replacement percentage are equal.

Alternative hypothesis (H1): the mean compressive strength with different admixture

Table16: replacement percentage are not equal.

Percentage replacement	Mean compressive
0.00	23.30
0.05	21.96
0.10	21.24
0.15	20.10
0.20	18.85

Table17: Model summary

Total sum of square	Sum of square between groups	Sum of squares within groups	Mean squares between groups ms-a	Mean square with groups ms-e	F statics ms-a ms-e
344.59	233.19	111.40	46.64	3.71	12.57

Critical f- value

F (a, k – 1, N – k) = f(0.005, 4, 16) = 3.01

Decision: since f- statistics > F unit, we reject the null hypothesis

Table18: Correlation result

Crushing age	Correction coefficient
7	0.94
14	0.94
21	0.99
28	0.99
Average	0.97

The correlation coefficient indicating a strong positive correlation between the concrete Straight on different days.

IV. Conclusion

This study indicated that the concrete mixes of 0.00 to 0.10 replacement attained the required strength of 25 n/mm2 at the crushing age of 28 days. Though the control mix gains strength faster and also recorded the highest strength, Yet the study has proved that the combination of PP/PL Ash can serve as a good replacement for cement, since they gained adequate strength and are very affordable for use. Though more industrial preparation should be added to make the ash finer. Their slow rate of gaining strength may result from it pozzolanic nature. The 0.97 correlation from the mathematical model its another good indicator that the pp/pl ash can share as add mixture with cement with about 10% replacement.

Recommendation for further studies

Further laboratory test should carry out to check the result and reaction when the ash is fine

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