Investigation Of The Effect Of Palm Bunch Ash On Concrete Properties.

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Abstract – The effect of Palm Bunch Ash (PBA) on concrete properties was investigated. The investigation studied the effect on compressive, flexural, split tensile strength, setting time and workability of concrete if Ordinary Portland Cement (OPC) was replaced with 0%, 5%, 10%, 15%, 20% and 25% PBA. Concrete specimens were prepared with a mix aggregate of 1:2:4 and water/cement ratio of 0.6. The concrete samples were cured for 7 and 28 days respectively. Compressive, flexural and split tensile strength decreased as the content of PBA was increased. At 5% PBA the workability decreased as the content of PBA was increased, while the setting time increased as the PBA content was increased. For all the parameters tested, the significant effect started occurring at between 10-15% PBA. At 15% PBA, the PBA starts acting as retarding agent in concrete. At 5% PBA content, a savings in cost of about 2.2% is achievable per m^3 of concrete.

Keywords-Palm Bunch Ash, Cement, Compressive Strength, Flexural Strength, Split Tensile Strength, workability, setting time.

1. INTRODUCTION

The demand for cement world-wide is on the increase. The cost of cement is also rising daily. Concurrently with the rapid expansion of construction activities, housing and other buildings, and at the same time the rising cost of production with serious shortage of construction materials that will play a critical role in our long future, the discovery of alternative building materials that are cheaper and more readily accessible has become very important [1].

Also cement is among the most energy intensive construction materials. To reduce the greenhouse effect, some mineral admixtures have been studied as partial replacement for cement in plain and reinforced concrete [1].

The production of one tonne of cement liberates about one tonne of CO_2 to the atmosphere, as a result of de-carbonation of the limestone in the kiln during combustion of fossil fuel [2]. The contribution of Ordinary Portland Cement (OPC) production world-wide to the greenhouse gas emission is estimated to be about 1.35 billion tonne annually or about 7% of the total greenhouse emissions to the earth's atmosphere [3].

Fly ash, rice husk ash, palm oil fibre ash, palm kernel shell ash, granulated blast furnace slag and silica fume are some of the materials that have been deployed in experiments to investigate possible quantities that could replace cement while still retaining strength and other properties. Palm Bunch Ash is an agro-waste generated from the Palm Oil Industry. It is obtained by the combustion of the palm fruit bunches The raw materials in the form of fresh fruit bunches are supplied to the palm oil industry and its process produces a large amount of solid waste materials in the form of fibres, shells and empty fruit bunches [4].

Production of palm oil from palm fruit is a major occupation in tropical climate countries. Indonesia and Malaysia together are said to be the largest producers of palm oil, that is, nearly 55,800MT of annual production. Palm oil trees are abundant in the Niger Delta and in some other southern states in Nigeria. However, it is important to mention that Indonesia and Malaysia actually obtained the first palm seedlings from Nigeria.

The palm oil tree is an economic tree as a result of the following:

(a) The palm kernel seeds are used in the soap manufacturing industry.

(b) The tree and the palm kernel bunches are used in the manufacture of foot mats.

© The leaves and trunks are utilized in the weaving of baskets in African countries.

(d) Local drinks are obtainable from the tree either while still growing or after they have been cut down.

Even with the above use of the palm oil tree, large quantities of the palm fruit bunches still remain unused thereby constituting an environmental issue in terms of how to dispose them.

The environmental pollution arising from the production of cement and the need to reduce the quantity amount of cement used in the construction industry is the basis for embarking on this research involving waste products that could be harmful to the environment. Incorporation of these waste products further leads to the sustainability of the environment.

The PBA is classified as Class F according to ASTM C618 [5]. It is siliceous and aluminous with virtually little or no cementation value, therefore for pozzolanic reaction it has to be combined with little lime [6].

Palm Oil Fibre Ash has been successfully used as an additive in cement construction [7]. [4] studied the performance of High Strength Concrete using Palm Oil Fuel Ash as partial cement replacement. They used replacement levels of 0%, 5%, 10%, 15%, 20% and 25% on M60 Grade concrete. [1] investigated Palm Kernel Shell Ash (PKSA) as partial replacement in High Strength Concrete. They used replacement levels of 0%, 25%, and 50%. They concluded as follows:

(a) PKSA as a partial replacement of cement in fresh concrete decreases workability when compared to control concrete made with PKSA.

(b) the addition of PKSA into the concrete mixture did not improve its ultimate compressive strength for 7 days curing period, but after 28 days and 56 days, only small increase in compressive strength with addition of PKSA was observed.

© flexural strength was reduced with increase in PKSA content.

(d) Split tensile Strength was not appreciably affected by the replacement of cement with PKSA, the higher the content of the PKSA in the concrete the lower the Split Tensile Strength.

(e) water absorption reduced as the content of PKSA increased.

(f) they recommended that optimum replacement level of OPC with PKSA occurs at 25% replacement level. After 25% PKSA replacement, compressive strength started to reduce.

[8], investigated Palm Kernel Husk Ash (PKHA) as an admixture (accelerator) between (0-25%) PKHA replacement in concrete. He concluded that the setting time of the concrete containing PKHA increases as the PKHA increases, between (0-25%) PKHA and thereafter the setting time starts to decrease as the PKHA increases. The compressive strength of the concrete decreases as the content of PKHA was increased but remains unaffected after 25% PKHA.

This study evaluated the effect of PBA on normal Grade 20 concrete. Properties investigated include: compressive, flexural, Split Tensile strength, workability and setting times for 0%, 5%, 10%, 15%, 20% and 25% PBA replacement in concrete. [1] , investigated replacement levels of 0%, 25%, and 50% on Grade M60 concrete. This study therefore tended to fill the gap between (0%-25%) replacement levels.

2.0 MATERIALS AND METHODOLOGY

2.1 MATERIALS

The following materials were used for the experimental work: OPC, palm bunch ash, sand, granite and water.

2.1.1 Cement

OPC (used was obtained from DANGOTE INDUSTRIES PLC, Nigeria). The cement properties conformed to [9] and [10].

2.1.2 Palm Bunch Ash

The PBA was obtained by burning the palm bunches from a palm oil production factory at ALUU, a village near CHOBA, the location of the University of Port Harcourt, Nigeria. The palm bunches was burnt to ashes at the Civil Engineering Laboratory of the Rivers State University of Science and Technology, Nkpolu, Port Harcourt. The PBA was sieved with a 600 micron sieve.

2.1.3 Fine Aggregate

Sand used for the production of concrete is clean river sand with maximum size of 4.75mm with specific gravity of 2.80. It was obtained from Imo River in Oyigbo near Port Harcourt. The sand particles conformed to the requirements of [11].

2.1.4 Coarse Aggregate

The coarse aggregate used is granite with an average size of 10mm and was obtained from Crush Rock Industries, in Ishiagu in Ebonyi State, South Eastern, Nigeria.

2.1.5 Water

Water is an essential ingredient in the production of concrete. It actively participates in the chemical reaction with cement and aggregates. The potable water used for the experiment was obtained from the Civil Engineering Laboratory of the Rivers State University of Science and Technology, Nkpolu, Port Harcourt. It was checked and found to be free from acid, organic matters, suspended solids, alkalis and other impurities which may have adverse effect on the properties of concrete. The potable water conformed to [12].

2.2 METHODOLOGY

2.2.1 Mix Proportion

Mix proportioning by weight was used. The cement and dried total aggregates ratio was 1:2:4. PBA was used to replace OPC at replacement levels of 0%, 5%, 10%, 20% and 25% by weight. [13] used PKSA replacement levels of 25%, 50%, 75% and 100%. The mix proportions of the different mixes are shown on Tables 1

Table. 1: Mix Design for Strength Tests

Mix Design	PBA Replacement	Water (Kg)	Cement (Kg)	Coarse Aggregate (Kg)	PBA (Kg)
HSCPBA 1	0	4.73	4.12	16.47	0.00
HSCPBA 2	5	4.73	3.91	16.47	0.21
HSCPBA 3	10	4.73	3.71	16.47	0.41
HSCPBA 4	15	4.73	3.50	16.47	0.62
HSCPBA 5	20	4.73	3.30	16.47	0.82
HSCPBA 6	25	4.73	3.09	16.47	1.03

2.2.2 Compressive Strength

Ninety (90) cube specimens of 150mmx150mmx150mm each were cast. 3 cubes were cast for each replacement level and cured for 7 and 28 days respectively. The average value of the compressive strength of the three cubes was obtained for each replacement level. The specimens were de-moulded after 24 hours and cured in a curing tank containing water. This was done in accordance with [14].

2.2.3 Flexural Strength

For the Flexural Strength a test mould of 100mmx100mmx500mm was used. The test samples were cast with different percentages of PBA. Mix ratio was 1:2:4 and water/cement ratio of 0.6. They were cured for 7 and 28 days. The Flexural Strength test was performed according to [15].

2.2.4 Split Tensile Strength

Cylindrical concrete cubes of 300mm in height at 50mm diameter using a mix ratio of 1:2:4 were cast and left to cure for 7 and 28 days respectively. The test was performed in accordance with [16].

2.2.5 Workability

The workability of the concrete with various replacement level of OPC with PBA was carried out using the Concrete Slump Test. Concrete mix ratio was 1:2:4 and a water/cement ratio of 0.6. The Slump test was carried out in accordance with [17].

2.2.6 Setting Time

The initial and final setting times for concrete cast with the various percentages of PBA was determined in accordance with [18].

3.0 TEST RESULT AND DISCUSSIONS

Table 2 is a summary of the compressive, flexural and Split Tensile strengths of the concrete cube mix at the various levels of OPC with PBA replacement at 7 and 28 days respectively, `

Table 2: Summary of the Compressive, Flexural and Split Tensile Strengths of the Concrete Cube Mixes at 7 and 28 days.

PBA (%)	Compressive Strength (N/mm2)		Flexural Strength		Split Tensile Strength	
	7days	28days	7days	28days	7days	28days
0	20.29	24.59	6	10	2.26	2.55
5	19.25	24.15	5	9	2.12	2.41
10	17.93	22.22	5	8.5	1.98	2.26
15	17.33	20.74	5	8	1.79	2.12
20	16.74	19.11	4	6	1.63	1.84
25	14.96	17.33	4	5	1.41	1.56

3.1 Compressive Strength

Fig.1 illustrates the variation of compressive strength with PBA content. The compressive strengths at 7 and 28 days, decrease as the PBA content increases. This can be attributed to the fact that OPC has more bonding strength than PBA. Up to 5% PBA content, concrete can be produced by mixing 5% PBA with 95% OPC without experiencing loss of compressive strength. Between 0% and 5% PBA content, values of the compressive strength obtained compares favourably with those of Grade 20 concrete. In summary, at 7 days the compressive strength for the control mix (0% PBA) is 20.29N/mm^2, while that at (5% PBA) is 19.25N/mm^2, while represents a 5% decrease in strength. For the 28 days compressive strength, the strength of the control mix (0% PBA) is 24.59N/mm^2, while that at (5% PBA) is 24.15N/mm^2, which represents a 2% decrease.

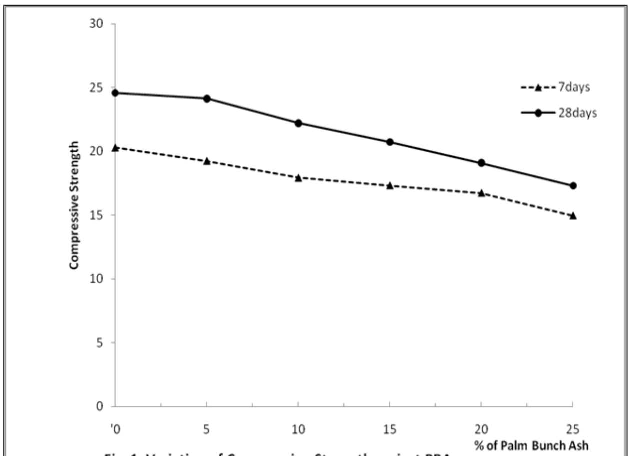

Fig. 1: Variation of Compressive Strength against PBA

3.2 Flexural Strength

Fig. 2 shows the variation of the flexural strength with PBA content. Generally the flexural strength decreases as the PBA content increases. Flexural strength is $6N/mm^2$ for (0% PBA), while it is $5N/mm^2$ at (5% PBA) content, which represents a 17% decrease. The flexural strength at 28 days for (0% PBA) is $10N/mm^2$, while that at (5% PBA) is $9N/mm^2$ which represents a 10% decrease. As explained for the result of the compressive strength, the primary reason for the trend of result is that OPC has more bonding strength than PBA.

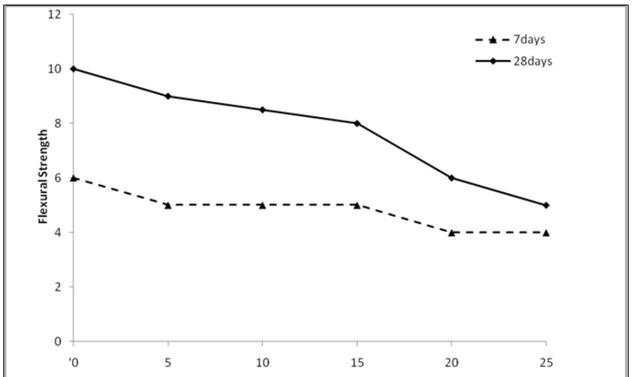

Fig. 2: Variation of Flexural Strength against PBA Content

3.3 Split Tensile Strength

The variation of the Split Tensile strength with the PBA content is shown in Fig. 3.

There is a decrease in Split Tensile Strength as the PBA content increases. Split Tensile Strength is 2.2 $6N/mm^2$ for (0% PBA), while it is $2.12N/mm^2$ at (5% PBA) content, which represents a 6.2% decrease. The Split Tensile strength at 28 days for (0% PBA) is $2.25N/mm^2$, while that at (5% PBA) is $2.41N/mm^2$ which represents a 5.5% decrease. As explained for the result of the compressive strength, the primary reason for the trend of result is that OPC has more bonding strength than PBA.

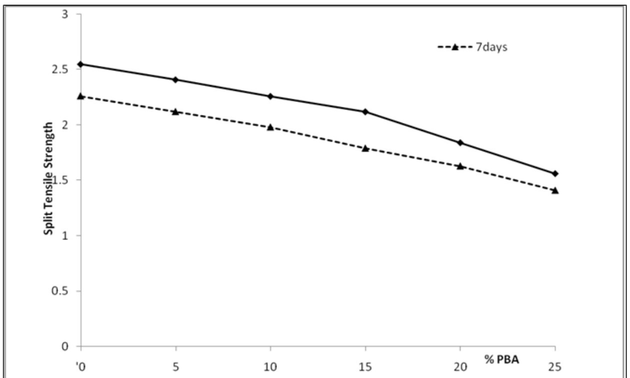

Fig. 3: Variation of Split Tensile Strength against PBA content

3.4 Workability

Fig. 4 shows the variation of the workability of concrete mixed with various percentages of PBA.

The slump test result shows that that the workability decreases as the content of PBA is increased. [1], explained that this is due to the fact that a lesser amount of free water is available in the presence of PKSA. The PKSA particles according to their findings were more porous and possessed a greater specific surface than cement.

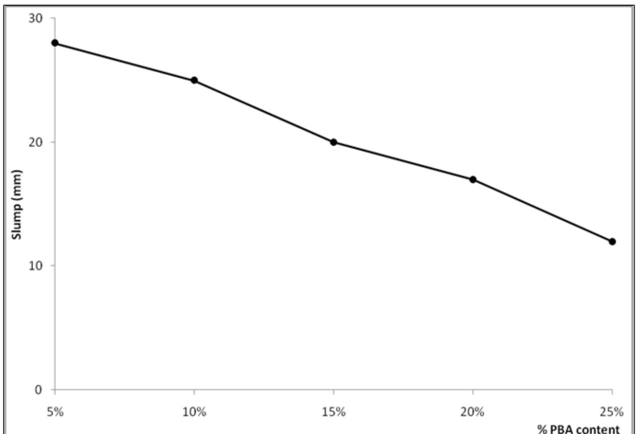

Fig. 4: Variation of Slump against PBA content

3.5 Setting Time

Fig. 5 shows the variation of the initial and final setting times with the PBA content. Between (0-5% PBA), the initial and final setting times increased as the PBA content was increased. Between (5% - 15% PBA) there is no increase in the initial and final setting times. Between (20-25% PBA), the initial an final setting times increase as the PBA is increased. This is as result of the fact that the rate of hydration reduces as the content of the PBA is increased due to the increase in the amount of silica from the PBA.

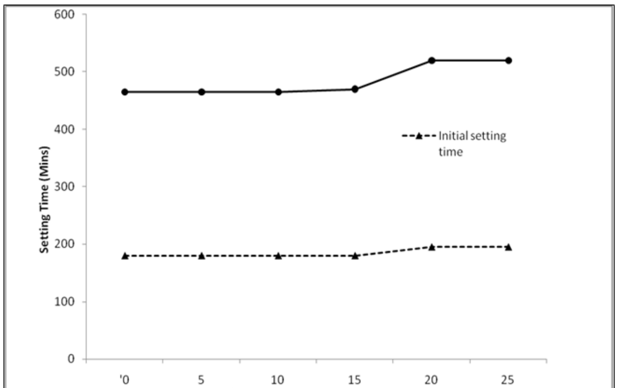

Fig. 5: Variation of Setting Times against PBA content

3.6 Chemical Analysis of Palm Bunch Ash

Table 3 is the chemical analysis of the Palm Bunch Ash. The dominate compound is ---%, followed by ----%.

3.7 Cost Benefit Analysis for Use of Palm bunch Ash

Tables 4.1 and 4.2 are the cost benefit analysis based on the production of $1m^3$ of concrete using 0% PBA and that of 5% PBA respectively. A review of the two tables shows that a cost saving of 2.2% per m^3 of concrete can be made while using 5% PBA and 95% cement for concrete production, without losing compressive, flexural or Split Tensile Strength.

Table: 4.1: Cost Analysis of 0.038m^3 of Plain Concrete

ITEM NO	ITEM DESCRIPTION	QUANTITY REQUIRED	UNIT	RATE (N)	AMOUNT
1.1	Cement	7.88	Kg	34.00	267.92
1.2	FA	15.72	Kg	2.00	31.44
1.3	CA	31.44	Kg	3.50	110.04
1.4	Water	6.46	L	0.80	5.168
1.5	Workmanship		sum	-	6000
1.6	Overhead		sum	-	4000
TOTAL					10414.568
Contingency (5% of Total Cost)					520.7284
Overall Total					10935.2964
Cost for 0.038m^3					415.5412632

	Table 4.2: Cost Analysis for 1m^3 of Concrete Containing 5% PBA				
ITEM NO	**ITEM DESCRIPTION**	**QUANTITY REQUIRED**	**UNIT**	**RATE (N)**	**AMOUNT**
2.1	Cement	7.49	Kg	34	254.66
2.2	PBA	0.39	Kg	10	3.9
2.3	FA	15.72	Kg	2	31.44
2.4	CA	31.44	Kg	3.5	110.04
2.5	Water	6.46	L	0.8	5.168
2.6	Workmanship	-	sum	-	6,000.00
2.7	Overhead	-	sum	-	4,000.00
	TOTAL				10405.208
	Contingency (5% of Total Cost)				520.2604
	Overall Total				10925.4684
	Cost for 0.038m^3				415.1677992

4.0 CONCLUSION

The conclusions derived from this study are as follows:

(a) There is a decrease in compressive, flexural and split tensile strengths at both 7 and 28 days as the PBA content is increased. Optimum cement replacement with PBA occurs at 5% PBA replacement level.

(b) The workability of the concrete decreases as the PBA content is increased.

© The initial and final setting times increased from 20% PBA replacement level.

(d) PBA could be used as an admixture (retarder) in concrete production from 20% PBA replacement level with some strength reduction, which can serve as lightweight concrete.

5.0 REFEENCES

[1] Olowe, K.O. and Adebayo, V. R. “Investigation on Palm Kernel Ash as Partial Cement Replacement in High Strength Concrete”. SSRG International Journal of Civil Engineering. Vol. 2, No. 4, 2015, pp. 48-56.

[2] Mccafrey, R. “Climate Change and the Cement Industry”. GCL Magazine, 2001.

[3] Malhotra, V.M. “High Performance, High-Volume Fly Ash Concrete”. Concrete International. Vol. 24, No. 7, 2002, pp. 390-34.

[4] Swaroopa, R.M. and Tejaanresh, M. “Performance of High-Strength Concrete Using Palm Oil Fuel Ash”. International Journal of Engineering Research and Applications. Vol. 5, No. 4, 2015, pp. 8-12.

[5] ASTM C618 -15.-Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete. American Society for Testing of Materials. West Conshohocken, PA. 2015.

[6] Otoko, G.R., Isoteim, F., Chinweike, I.S. and Oluwadare, J.O. “Soft Soil Stabilization Using Palm Oil Fibre Ash”. Journal of Multidisciplinary Engineering, Science and Technology. Vol. 3, No.5 2015, pp. 4954-4958

[7] Awal, A.S.M. and Hussin, M.W. “Some Effects of Durability Performance of Concrete Incorporating Palm Oil Fuel Ash”. Proceedings of Fifth International Conference in Structural Failure, Durability and Retrofitting. Singapore, 1997, pp. 210-217.

[8] Otunyo, A.W. “Palm Kernel Husk Ash as an Admixture (Accelerator) in Concrete. Nigerian Journal of Technology, Vol. 30, No. 3, 2011, pp. 60-66.

[9] BS 12; 1996 – Specification for Portland Cement. British Standards Institute, London, United Kingdom.

[10] BS 4450-3; 1978 – “Methods of Testing Cement. Physical Test”. British Standards Institute, London, United Kingdom.

[11] BS 882;1992 – “Specifications for aggregates from natural sources for concrete”. British Standards Institute, London, United Kingdom

[12] BS 3148; 1980 - “Methods of test for water for making concrete”. British Standards Institute, London, United Kingdom

[13] Ekeocha, N.E. and Agwuncha, F.N. “Evaluation of Palm Kernel Shells for Use as a Stabilizing Agents of Lateritic Soils”. Asian Transactions on Basic and Applied Sciences. Vol. 4, No. 2, 2014, pp. 1-7.

[14]] BS EN 12390-3 Part 3; 2002. - “Testing Hardened Concrete. Compressive Strength of Test Specimen”. British Standards Institute, London, United Kingdom

[15] BS EN 12390-5; 2000. – “Testing Hardened Concrete. Flexural Strength of Test Specimen”. British Standards Institute, London, United Kingdom.

[16] BS EN 12390-6; 1983 – “Testing Hardened Concrete. Tensile Splitting Strength of Test Specimen”. British Standards Institute, London, United Kingdom.

[17] BS 12350-2; 2009 – “Testing of Concrete – Method for determination of Slump”. British Standards Institute, London, United Kingdom.

[18] BS EN 196-3; 1995 – “Method of Testing Cement. Determination of Setting Time and Soundness”. British Standards Institute. London, United Kingdom.