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Physio-Mechanical Properties of Ile-Oluji Cocoa Pod Husk Waste (CPHW) as a Partial Replacement of Cement in Concrete: Panacea for Sustainable Construction Material

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ABSTRACT

This study investigates the viability of Cocoa Pod Husk Waste Ash [CPHWA] as a partial replacement for cement in concrete production due to the high cost of cement and its adverse environmental impacts in Ile-Oluji, Ondo State, Nigeria. The process involved the use of Concrete cubes which were produced with CPHWA at three different ages [7days, 14days, and 28days] with replacement levels of 0%,5%,10%, and 15%. The results show that a 5% replacement of CPHWA yielded concrete with moderate workability, while a 10% replacement achieved compressive strengths within the desired range of 20 N/mm² to 25 N/mm² after 28 days of curing. These findings suggest promising prospects for integrating CPHWA into concrete production, offering potential benefits for the construction industry and civil engineering projects in terms of cost-effectiveness and environmental sustainability.

Keywords: Physio-Mechanical Properties, Cocoa Pod Waste, Partial Replacement, Concrete composite, Potential Material.

1 Introduction

In developing nations, researchers have advocated for the use of alternative binding materials to partially replace cement in concrete production due to the upsurge in the cost of cement which has attributed to production of cement with low grades, primarily driven by rising expenses of industrial gas, foreign exchange, and other raw materials essential for its manufacturing. Cement, a crucial material in various concrete works, particularly in Nigeria, has become increasingly unaffordable and inaccessible. Despite this, the demand for urban housing and other construction projects reliant on cement continues to soar exponentially, propelled by rapid population growth and urbanization. Concrete, being one of the major construction materials worldwide, holds significant potential in this regard. This shift could alleviate the cost burden of construction, rendering low-cost buildings feasible in both rural and urban areas of developing countries that heavily rely on cement as their sole binding material in construction projects

2 Literature Review

In Nigeria presently, the construction community's interest in utilizing waste or recycled materials in concrete production is growing due to the increasing emphasis on sustainable construction that is environmentally friendly [27,10]. The use of waste materials in building construction is of utmost importance in mitigating climate change as improper disposal of waste into the environment directly results in the damage of natural climatic conditions [12]. In Nigeria, cocoa is predominantly grown in many districts, primarily in South-Western Nigeria, with Idanre being the center of highest production [5]. In southern Nigeria, cocoa, a seasonal crop, constitutes the main and often sole source of income for most farmers. The improved breed variety can produce double harvests in a season, resulting in increased CPW production [5]. When cocoa is harvested, the pod husk is often disposed of as waste due to many people being unaware of its economic benefit. Consequently, heaps of cocoa pod husk waste are commonly found in most cocoa-growing communities in Nigeria, posing a management challenge for many rural areas [4], most importantly farmers that have heaps of cocoa pod waste on their farmland. This waste are burnt, and the resulting ash and volatile gases is blown away by the wind. The chemical and physical properties have been identified to have properties that binds soil together due to its cementation potentials [25]. In spite of this, CPHW, as indicated by [21], can serve as a stabilizer for weak lateritic soils in road construction. Therefore, it should be viewed as a resource rather than waste, thereby reducing Nigeria's environmental burdens. Nowadays, the usage of concrete is increasing annually due to the rapid development of the construction industry. Concrete is not only used in building construction but also in various other areas such as road construction, bridges, harbours, and many others.

The dominating factor affecting housing systems worldwide is the high cost of construction materials. In rural areas and certain cities, there has been a decline in the use of cement due to its high cost, resulting in a shortfall in the construction of buildings using concrete materials. Additionally, most formal housing units are unaffordable for the majority of the population. The cost of materials in the construction industry remains unpredictable due to their expense, making affordability a challenge. However, there is a growing demand for affordable housing systems in both rural and urban areas of developing countries [21]. Various schemes have been proposed to reduce conventional building material costs. One suggestion is to use non-conventional local construction materials, including agro-wastes and residues, as partial or full replacements for conventional materials. [24]: Reported that countries with abundant agro-wastes can utilize these materials as potential replacements in the construction industry, as highlighted in previous studies [21].

The high cost of construction materials is a dominating factor affecting housing system around the world. In Nigeria, the annual deficit in the building industry amounts to about 200,000 housing units [23]. Besides, most formal housing units are beyond the affordability level of the majority of the population due to the shortfalls. However, in recent times, the cost of materials used in the construction industry cannot be projected accurately, as they are expensive and not easy to afford. However, various schemes focusing on cutting down conventional building material costs have been proposed, aligning with the quest for affordable housing systems for both the rural and urban population in developing countries [22]. One of the suggestions put in place has been an alternative to use non-conventional local construction materials, including the possibility of using some agro-waste and residues as potential or full replacements.

Alternatively, Cocoa production is a major activity in West Africa, where about 66% of the world's cocoa beans are produced in major countries such as Nigeria and Ghana. The production of the beans results in the generation of large quantities of cocoa pods, which are mostly left on the farm to naturally decay (19). The wastes resulting from the agriculture industry represent 50% of the fresh weight of the total harvested production. In energy terms, this is equivalent to the potential of 90 million tons of oil. [20]. Also, heaps of cocoa pod Husk waste serves as homes for rodents and other pests which can cause damage on the farm. [5]. Even though cocoa has been cultivated in Nigeria for decades, information on the adequate use of the waste by construction industries is rare. According to research findings, cocoa pod husk contains potassium oxide [68.26%], magnesium oxide [3.59%], calcium oxide [2.02%], iron oxide [1.75%], silicon oxide [9.727%], and other oxides in minute quantities. In their research where [23] conducted the feasibility of using CPW as a stabilizer in the production of compressed earth bricks was investigated. They found that Potassium (K2O) constituted the highest proportion at [25.61%] by weight, making the ash a natural source of alkaline. Their data showed a gradual increase in the engineering properties of the stabilized earth bricks as the CPWA content increased from 0% to 10%, before slightly declining after subsequent additions. They concluded that the optimum amount of ash required for stabilizing the earth is 10% by weight. Their study indicated that effective stabilization of earth with similar characteristics for bricks production requires lower CPWA contents, as higher content reduces the engineering properties.

The research work is to determine the applicability of Cocoa Pod Waste Ash (CPHWA) as a partial replacement for cement in concrete production for low cost buildings in developing countries. This study focuses on the properties of concrete through the partial replacement of cement with CPHWA. That is, workability of concrete mixtures mixed with 0%, 5%, 10% and 15% respectively of CPHWA and compressing force of the concrete mixture with CPWA after 7days, 14days with 28days of curing. [9], positioned that the use of CPHWA as composites in concrete substance was concluded to increase the setting times of Ordinary Portland Cement and decreases the drying shrinkage with increase in CPHWA addition. The incorporation of CPWA as composite in concrete increases the slump of concrete up to value of 1.0% addition while determine workability of pozzolan on concrete. As such, the workability of concrete can be categorized into three types: unworkable concrete [concrete with a very little amount of water], medium workable concrete [concrete that is relatively easy to mix, transport, place, and compact without segregation], and highly workable concrete [concrete very easy to mix, transport, place, and compact] [11]; in [8]. They further stated that the use of CPHWA as an admixture in concrete effectively enhances the compressive strength, with the optimum strength achieved at a 0.6% addition. It possesses the quality of a material suitable for use as a water-reducing or water-repellent composite in concrete.

Figure 1: Pictorial view of heap of CPHW on cocoa farm

3 Materials and Methods

The experimental procedures include the selection of materials, concrete mix-design, as well as the preparation and testing of concrete. A total of 36 cubes were tested to achieve the objective of the research. A total of 36 cubes were tested to achieve the objective of the research. And raw materials used include: Ordinary Portland Cement [OPC], Dangote brand precisely, coarse aggregate size of 12.5mm, river sand, CPHA and portable water that conformed to [13] requirements and other relevant tools. Dried cocoa pod husks were obtained at Ile-Oluji, Ondo State. The materials were gathered in the open and burned into ashes as shown in Figure 2 below. The residue from the burning process were allowed to cool down for a period of 24 hours before processing. Research has indicated that burning in dried state yield more powered than the fresh state of cocoa pod husks [1]. The ashes obtained were sieved using a British Standard [BS] sieve 300μmm, this was done to remove all partially burnt carbon particles in the CPHW so as to obtain the reactive form of the ashes, which are mostly in a very fine state.

Figure 2: Dried Burnt cocoa pod husks waste

The study abducted mix ratio of 1:1.5:3 at the initial trial experimentation in order to meet up with the objective strength of 20MPa.

Table 1: The composition of oxides in Cocoa Pod Husk Waste Ash (CPHWA).

Oxides in the Ash	**Mass in percentages (%)**
Sio2	9.727
Fe2o3	0.447
Al2o3	3.444
Na2o	0.444
Tio2	0.140
Cao	8.470
Mgo	4.297
So3	2.171
P2o5	0.276
Cl	0.155
K2o	25.610
Mno	0.090
Lol	32.000

It follows the batching of materials by weigh. The percentage additions of opc for CPHWA were 0.0%, 5%, 10%, and 15% and the mixing procedures were abducted accordance to bs 188: Part 108: 1983 practice after dividing the materials into four [4] stages. The first stage was by mixing cement, fine and coarse aggregates which acts as control with the above-mentioned ratio. Stage two was the supplement of cement by 5% of CPHWA and subsequently up to the last stage for replacement of cement by 15% of CPHA, where the weigh summary shown from table [2] below:

Table 2: Weight proportion of materials used for the experiment

Specimen for case study	**Mass of cement (kg)**	**Mass of fine aggregate. (kg)**	**Mass of coarse aggregate (kg)**	**Mass of ash (kg)**	**Mass of water (ml)**
0.0%	9.0	13.5	27	0.000	3800
0.5%	8.55	13.5	27	0.45	4200
10%	8.1	13.5	27	0.9	4700
15%	7.65	13.5	27	1.35	5100
TOTAL	33.3	54.00	108	2.7	14500


Figure 3: Batching of materials done by weighing

Slump test examination was conducted on the fresh concrete composite to ascertain the efficiency of the concrete by setting the slump cone, and it was filled in three strata, each stratum was blown 35 times using a bullet nose and this is done to all the mix ratios of the concrete. In 2 – 5sec. the cone was removed and set it next to the concrete, and the slump was determined. Then, the concrete was casted into the metal cubes of 150mm x 150mm x 150mm of Ordinary Portland Cement [Dangote brand], the trials go with zero percent of CHPA which acts as control. The second trial go with five percent of CHPA to replace cement and subsequently, fifteen percent of CPHA to replace the cement and total 36 cubes of concrete were casted in other to determined their compressive strength. The samples were demolded after 24 hours and kept in a curing tank for 7, 14, and 28 days respectively, for early age and mature testing according to [18].

Figure 5: Slump test

Figure 4: Fresh concrete cubes

The compression test was conducted by using compressive test machine set for that purpose at the strength and material laboratory of Federal Polytechnic, Ile-Oluji as indicated in the test method of [16] after when the mass of each cube has been taken. An increasing compressive load was applied to the specimen until failure occurred to obtain the maximum compressive load.

Figure 6a: Cubes during testing

Figure 6b: Cube after testing

4 Results and Discussion

This chapter presents the results of the different tests conducted with reference to laid down principles. The findings arrived at as a result of the strength behaviour of the specimens in this experiment was evaluated in terms of physical properties of cocoa pod husk waste ash [CPHWA] concrete such as Particle size Analysis, Moisture content, workability [Slump Test] and compressive strength.

Table 3: Showing Particle Size Analysis

S/N	SIEVE SIZE	MASS RETAINED (%)	PERCENTAGE RETAINED (%)	PERCENTAGE CUMMULATIVE RETAINED (%)	PERCENTAGE PASSING (%)
1	10.000	4.600	0.920	0.920	99.080
2	5.000	49.800	9.960	10.880	89.120
3	2.000	102.300	20.460	31.340	68.660
4	1.000	33.700	6.740	38.080	61.920
5	0.500	120.100	24.020	62.100	37.900
6	0.250	93.900	18.780	80.880	19.120
7	0.100	80.800	16.160	97.040	2.960
8	0.075	8.000	1.600	98.640	1.360
9	<0.075	6.800	1.360	100.000	0.000

The table above shows the report of the particle size analysis, the lowest sieve size is 0.1, while highest sieve size is 10 and Mass Retained lowest is 4.60 while the highest is 120.10 and Percentage Retained [%] lowest is 0.92 while 24.02 is the highest and Cumulative Retained lowest is 0.92 while highest is 100.00 and Percentage Passing (%) lowest is 0.00 while highest is 99.08.

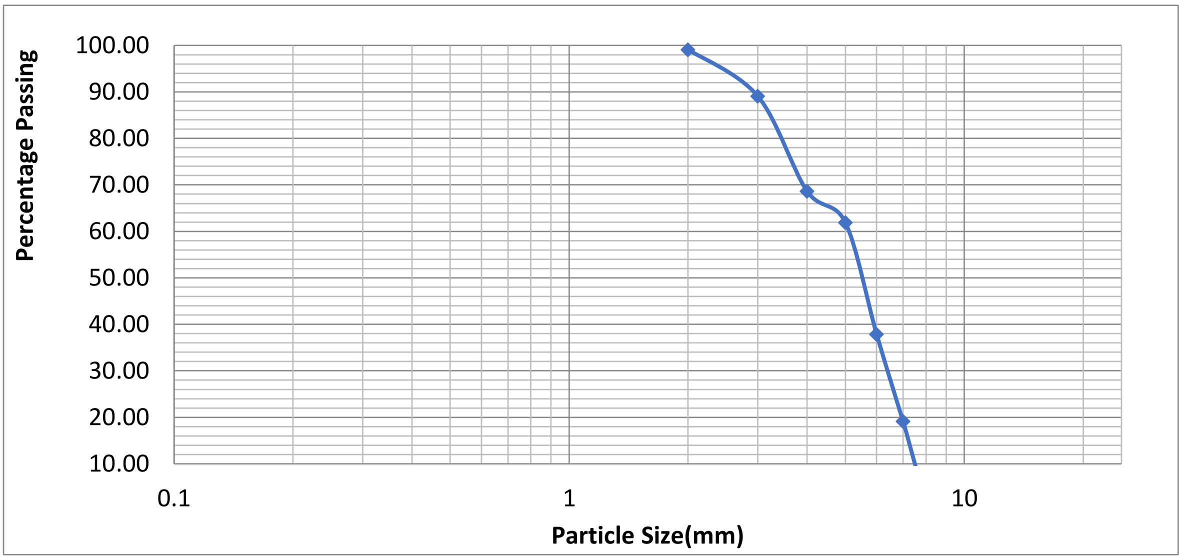

Figure 7: Graph showing percentage passing and particle size for Sieve Analysis

4.1 Workability Test [Slump Test]

The results of the Proportion of Cocoa Pod Husk Ash of concrete are summarized in Table 4 This process was carried out before casting the specimens. The results have been presented in Appendix A. From the Table, it was observed that in all the mixes, there were true slump.

Table 4: Showing the slump test for 14 days

Proportion of Cocoa Pod Husk Ash	Slump Values of Concrete (inches)
0%	1.5
5%	2.5
10%	1.5
15%	1.3

b. Weight of Concrete

Weight of all the samples [CPHWA] were taken after the curing process of all the three [3] different ages at 7 days for 0%, 5%, 10%, 15%

Table 5: Showing the weight of samples [CPHWA] after curing regime

DAYS	PERCENTAGES % [CPHWA]	WEIGHT (KG)
7	0	8.14
		8.18
		8.17
	5	8.16
		8.20
		8.18
	10	7.84
		7.82
		7.83
	15	8.20
		8.16
		8.18

The 14 days for 0%, 5%, 10%, 15%

Table 6: Showing the weight of samples [CPHWA] 14 days after curing regime

DAYS	PERCENTAGES % [CPWHA]	WEIGHT (KG)
14	0	8.20
		8.12
		8.16
	5	8.22
		8.00
		8.11
	10	7.58
		7.68
		7.63
	15	7.82
		7.74
		7.73

The 24 days for 0%, 5%, 10%, 15%

Table 7: Showing the weight of concrete (CPHA) 28 days after curing regime

DAYS	PERCENTAGES % [CPHWA]	WEIGHT [KG]
28	0	8.22
		8.42
		8.32
	5	7.88
		8.28
		8.08
	10	8.16
		8.22
		8.19
	15	7.96
		7.86
		7.91

4.2 Comprehensive Strength

The results of comprehensive strength tests are shown in table 7 for 7 days, 9 for 14 days and 10 for 28 days.

Table 8: Shows the comprehensive Strength result for 7 days

DAYS	PERCENTAGE [%]	LOAD [KN]	STRESS[N/mm2]	AVERAGE [N/mm2]
		700	31.11	
		600	36.66	
	0	650	28.88	28.88
		610	27.11	
		600	26.66	
	5	605	26.88	26.88
		610	27.11	
		580	24.44	
	10	580	25.77	25.77
		410	18.22	
		400	17.77	
7	15	405	18	17.99

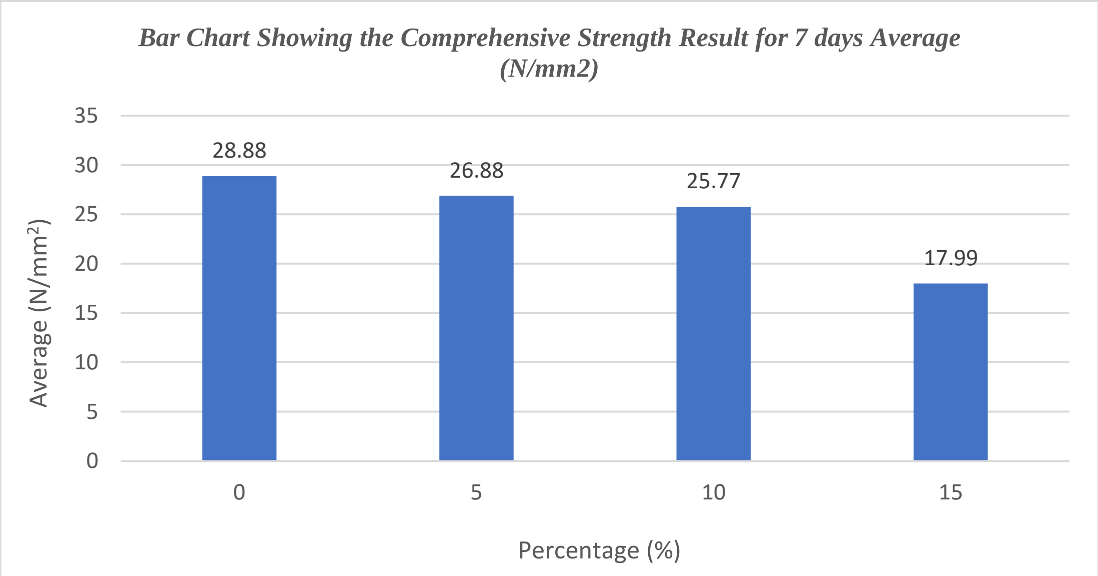

Figure 8: Bar Chart Showing the Comprehensive Strength Result for 7 days Average [N/mm2]

Result show above the compressive strength of CPHWA concrete for 0%, 5%, 10% and 15%, the load of CPHWA concrete after been determined the compressive strength as 700KN, 600KN and 650KN respectively for 0%, the strength of CPHWA concrete was calculated using the equation 1 as stated.

$$\frac{Load \times 1000}{Area} \quad \ldots\ldots 1$$

Table 9: Shows the comprehensive Strength result for 14 days

DAYS	PERCENTAE [%]	LOAD [KN]	STRESS [N/mm2]	AVERAGE[N/mm2]
14		710	31.55	
		520	23.11	
	0	615	27.33	27.33
		590	26.22	
		550	24.44	
	5	570	25.33	25.33
		440	19.55	
		490	21.77	
	10	465	20.26	20.52
		400	17.77	
		390	17.33	
	15	395	17.55	17.55

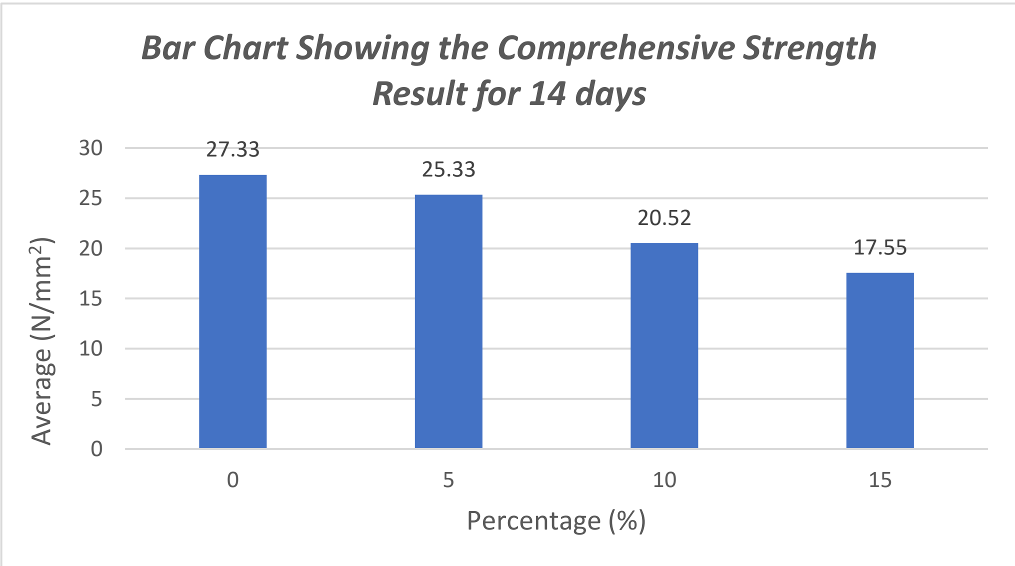

Figure 9: Bar Chart Showing the Comprehensive Strength Result for 14 days

The result show above the compressive strength of CPHA concrete for 0%, 5%, 10% and 15%, the load of CPHA concrete after determined the compressive strength as 710KN, 520KN and 615KN respectively for 0%, the strength of CPHA concrete was calculated using the same equation stated.

Table 10: Shows the comprehensive Strength result for 21 days

DAYS	PERECENTAGE (%)	LOAD (KN)	STRESS (N/mm2)	AVERAGE (N/mm2)
		700	31.11	
		710	31.55	
	0	705	31.33	31.33
		620	27.55	
		630	28	
	5	625	27.77	27.77
		560	24.88	
		580	25.77	
	10	570	25.33	25.33
		430	19.11	
		410	18.22	
21	15	420	18.66	18.66

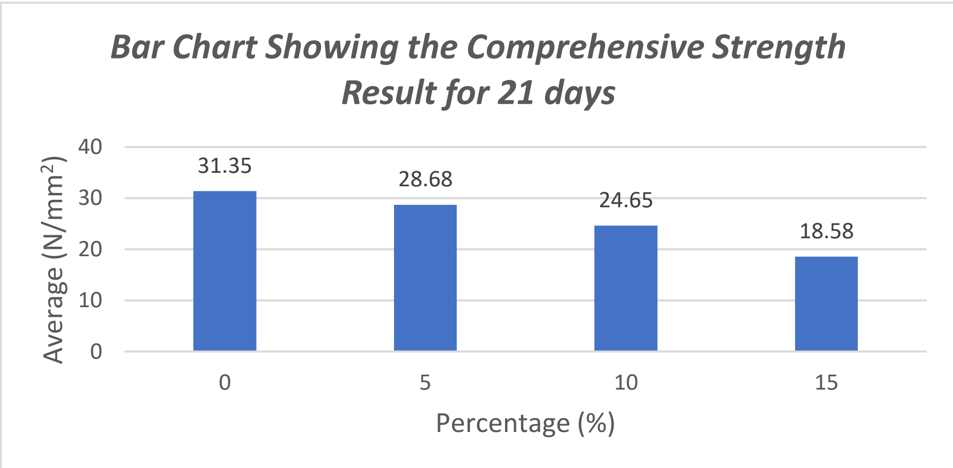

Figure 10: Bar Chart Showing the Comprehensive Strength Result for 21 days

Table 11: Shows the comprehensive Strength result for 28 days

Days	Percentage (%)	Load (KN)	Compressive Strength (N/mm2)	Average (N/mm2)
28		700	31.11	
		710	31.55	
	0	705	31.33	31.33
		620	27.55	
		630	28	
	5	625	27.77	27.77
		560	24.88	
		580	25.77	
	10	570	25.33	25.33
		430	19.11	
		410	18.22	
	15	420	18.66	18.66

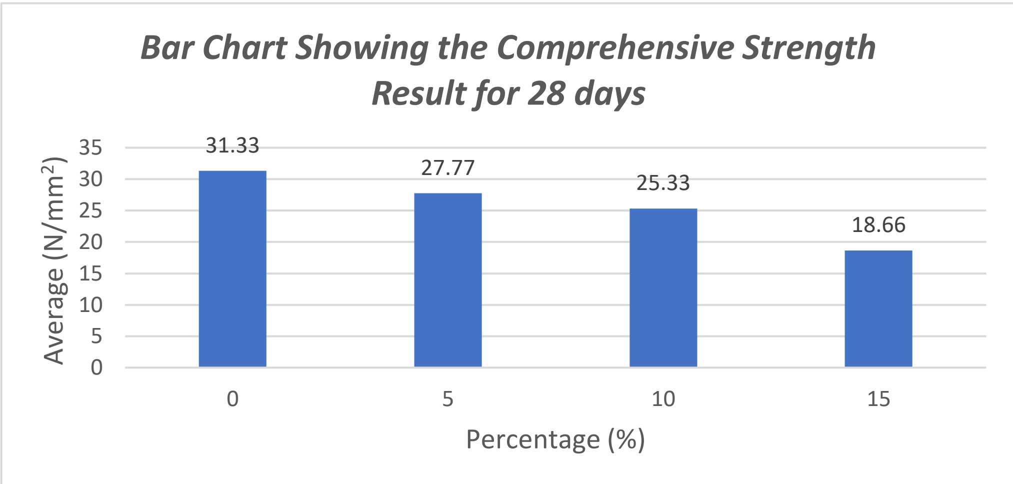

Figure 11: Bar Chart Showing the Comprehensive Strength Result for 28 days

The result shown above the compressive strength of CPHWA concrete for 0% 5%, 10% and 15%, the load of CPHWA concrete after been place on the compressive strength machine were 700KN, 710KN and 705KN respectively for 0%, the strength of CPHA concrete was calculated using the equation 1 as stated, the load is 700KN 710KN and 705KN.

Therefore, this study concludes that the slump test results for the concrete showed that incorporating Cocoa Pod Husk Waste Ash [CPHWA] as an admixture increases the workability of the concrete. This means that adding the admixture to concrete without reducing the water content can produce a mixture with a higher slump. This indicates that CPHWA is a water-reducing agent because of the possession of organic materials which acts as water absorbent in the mixture, and using CPHWA as a partial replacement for cement in concrete increases the slump of the concrete. In addition, the study proves that the compressive strength value of 27.77Mpa obtained at 5% of CPHWA for 28 days fall within the requirement of grade 20 concrete.

Furthermore, the use of CPHWA as partial replacement amendment in concrete should be encouraged in concrete works in an ambient weather condition in the developing countries especially Nigeria. Also, further study can be done on the effects of fresh and hardening properties of concrete for partial amendment of cement in concrete using cocoa pod husk waste ash as water reducing admixture for construction purposes in our environment.

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References

[1] Aberilla, J. M., Gallego-Schmid, A. and Azapagic, A. (2019). 'Environmental sustainability of small-scale biomass power technologies for agricultural communities in developing countries', Renewable Energy, 141, 493–506.

[2] Agele, S.O and Agbona A.I. (2008). Effects of Cocoa Pod Husk Amendment on Soil and Leaf Chemical Composition and Growth of Cashew (Anarcardium occidentale L) Seedlings in the Nursery American Eurasian Journal of Sustainable Agriculture, 2(3): 219-224.

[3] Agbona, A. I, Adebisi, S. L, Adebayo, S.A and Oladebeye, I.H. (2021). Growth response of oil palm (Elaeisguinnensis) to selected plant residues in Ile-Oluji rain forest zone of Nigeria. 39th Annual Conference of Horticultural Society of Nigeria 'CRIN 2021' held at Cocoa Research Institute of Nigeria on14th-18th November, 2021. Pp. 1125-1131.

[4] Agbona, A.I, Oladebeye, I.H., and Akinlosoye, J.J. (2022). Response of browse plant (Glyricidia sepium) to some selected organic waste in Ile-Oluji, South Western Nigeria. 40th Annual Conference of Horticultural Society of Nigeria 'HORTSON COAJ 2022' held at College of Agriculture, Jalingo, (COAJ). Taraba State, Nigeria. between 6th -10th November, 2022. Pp 293-299.

[5] Agbona, A.I, Oladebeye, I.H and Adebayo S.A (2023). Response of cocoa (Theobroma cacao, L) to different levels of organic waste in ile-oluji, south western nigeria. Journal of horticultural society of nigeria. ISSN:111-2733, Vol.2 (1), 2023.

[6] ACI Committee 211 (1991). Standard practice for selecting proportions for normal, heavy weight, and mass concrete. (Reapproved 2007), pp. 1–38.

[7] ASTM C 618-78. (2012). Standard Specification for Coal Fly Ash and Raw or calcined Natural Pozzolan for use in concrete

[8] Aslani, F., Ma, G., Wan, D.L.Y. and Le, V.X.T., (2018). 'Experimental investigation into rubber granules and their effects on the fresh and hardened properties of self-compacting concrete', ournal of Cleaner Production, 172, 1835– 1847.

[9] Audu Vincent E. M., Mamman Yakubu W., (2013). Use of Cocoa Pod Husk Ash as Admixture in Concrete, International Journal of Engineering Research & Technology (IJERT) Volume 02, Issue 11 (November 2013).

[10] Bamgbade, J.A., Kamaruddeen, A.M., Nawi, M.N.M., Adeleke, A.Q., Salimon, M.G. and Ajibike, W.A., (2019).'Analysis of some factors driving ecological sustainability in construction firms',Journal of Cleaner Production. 208, 1537–1545.

[11] Bamigboye, G.O., Nworgu, A.T., Odetoyan, A.O., Kareem, M., Enabulele, D.O. and Bassey, D.E., (2020).'Sustainable Use of Seashells as Binder in Concrete production: Prospect and challenges',Journal of Building Engineering, 101864.

[12] Bell, J., Paula, L., Dodd, T., Németh, S., Nanou, C., Mega, V. and Campos, P., (2018) 'EU ambition to build th world's leading bioeconomy - Uncertain times demand innovative Communications in Applied Sciences and sustainable solutions', New biotechnology, 40, 25–30.

[13] BS 8500-1 (2006). Concrete-complementary: Method of specifying and guidnace for the specifier. Carlsward, J., Emborg, M., Utsi, S. and Oberg, P. 2003. Effect of constituents on the workability and rheology of self-compacting concrete. In: O. Wallevik and I. Nielsson ed.3rd International RILEM Symposium on Self-Compacting Concrete. RILEM Publications SARL, Reykjavik, Iceland, pp. 143–153.

[14] BS EN 206-9 (2010). Additional rules for self-compacting concrete (SCC).Dinakar, P., Sethy, K.P.and Sahoo, U.C. 2013b. Design of self-compacting concrete with ground granulated blast furnaces lag. Materials and Design 43,pp. 161–169.

[15] BSI-BS 1881-111 (1993). Testing Concrete- Part 111: Method of Normal Curing of Test Specimen [20 Degrees C Method]

[16] Cohen, E., Peled, A. and Bar-Nes, G. (2019). 'Dolomite-based quarry-dust as a substitute for fly-ash geopolymers and cement pastes', Journal of Cleaner Production, 235, 910-919.

[17] El-Dieb, A. S. and Kanaan, D. M. (2018). 'Ceramic waste powder an alternative cement replacement– Characterization and evaluation', ustainable Materials and Technologies, 17, p.e00063.

[18] . European guidelines for self-compacting concrete, specification, production and use, (2005). pp. 1-68.

[19] Edward, Atwi, Nils Engler, Satyanarayana Narra and Andrea Schuch. (2019). Environmental effects of cocoa pods disposal in 3 west African Countries. Universitat Rostock, Agrar- Und. ISBN: 978-3-86009-487-7.

[20] Gontard, N., Sonesson, U, Birkved, M (2018). A research challenge vision regarding management of agricultural waste in a circular bio-based economy," Critical Reviews in Environmental Science and Technology, vol. 48, no. 6, pp. 614–654, 2018.View at: Publisher Site Google Scholar

[21] Hansen, S., Trammel, H., Dunayer, E., Gwaltney, S., Farbman, D. and Khan, S. (2003). ―Cocoa bean mulch as a cause of methylxanthine toxicosis in dogs‖. ASPCA Animal Poison Control Center, Urbana, IL Reterived from http//www.apcc.aspca.org.

[22] Hossain K.M. (2018). Lightweight Concrete Incorporating Volcanic Materials, ICE-Construction Materials Journal, Vol. 165, No. 2, pp.111-120.

[23] Mark Adom- Assamoah and Rusell Owusu Afrifa (2011). A comparative study of bamboo reinforced concrete beams using different stirrup materials for rural construction. International Journal for Computational Civil and Structural Engineering. 2(1): 1420-1436.

[24] Onyelowe, K. C. (2016).'Axial load and compaction behavior of pozzolan stabilized lateritic soil with coconut shell husk ash and palm kernel shell husk ash admixtures', Int J Innovat Stud Sci Eng Technol, 2, 24–29.

[25] Olanipekun, E.A., Olusola, K.O and Ata O. (2006). A comparative study of concrete properties using coconut shell and palm kernel shell as coarse aggregates. Building and Environment. Vol. 41 (3).

[26] Patrick Aoniamenga Bowan (2022). Cocoa Pod Husk Ash as Partial Replacement of Cement in Concrete Communication in Applied Sciences. ISSN2201-7372, Vol.10.

[27] Yalley, P. P. K. and Asiedu, E. (2015). Enhancing properties of earth brick by stabilizing with corn husk ash. Civil and Environmental Research. Vol. 3(11): 43-52. Retrieve from http://www.iiste.org .

[28] Yin, B.C.L., Laing, R., Leon, M. and Mabon, L. (2018) 'An evaluation of sustainable construction perceptions and practices in Singapore', Sustainable cities and society, 39, 613–620.