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Effects of Partial Replacement of Cement with Supplementary Cementious Material of Palm Fiber Ash on the Properties of Concrete

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Abstract: This study presents an overview of the work done in determining the impacts of palm fiber ash when used in conjunction with cement in the production of concrete. Four distinct percentage replacements were employed (from 0% to 15%). A mix design of 1:2:4 was used. 36 cubes in all were cast, 9 for the standard controls and 9 for each of the replacement percentages from 5 to 15%. All cubes underwent a 7, 14, and 28-day water curing process. The slump test result showed that the workability of the concrete decreased as palm fiber ash increased. The results also indicate that the compressive strength of palm fiber ash concrete increased as the percentage and curing age increased. 5% replacement obtained 7.96N/mm^2, 8.31 N/mm^2 and 8.83 N/mm^2 for 7, 14 and 28 days correspondingly. 10% replacement obtained 7.34 N/mm^2, 8.81 N/mm^{2}and 10.37 N/mm^2 at 7, 14 and 28 days respectively. The final replacement percentage (15%) obtained 8.06 N/mm^2, 10.66 N/mm^2 and 11.17 N/mm^2 at 7, 14 and 28 days.The aforementioned replacement was compared to the standard control (0% palm fiber ash) which obtained a compressive strength of 11.23N/mm^2, 11.83 N/mm^{2}and 11.85 N/mm^2 for 7, 14 and 28 days respectively. Although the compressive strength decreased when replacements were added, it was discovered that the percentage replacement of 15% produced a compressive strength that was 74.46 percent of the target strength and can be applied for plain concrete cement works. This study demonstrated that palm fiber ash is an effective partial cement material that can help cut down on the waste that the oil refining industries generate, hence reducing environmental pollution and producing concrete for sustainable development.

Keywords: Palm Fiber Ash, Percentage Replacement, CompressiveStrength, Cementitious Materials, Environmental Pollution

Introduction:

Concrete consumption has risen as a result of rapid global infrastructure development. Cement is an essential component of concrete; it acts as a binder and bonds the various solid components together to produce a cohesive mass (Karelia et al, 2021). The construction industry in particular is important when considering worldwide infrastructural development, given the continual increase in urbanization and population growth. The gross demand for cement needed as a component of concrete used in construction projects and other associated materials, on the other hand, continues to rise at an exponential rate.

The manufacturing of cement produces a significant amount of greenhouse gases, accounting for about 10% of global carbon (IV) oxide (CO2) emissions (Murali et al, 2021). This, combined with a rise in environmental awareness, has resulted in the creation of a number of innovative solutions of which supplementary cementitious materials are a part of. The usage of supplementary cementitious materials (SCMs) has gotten a lot of attention lately (Amran et al, 2021). It’s extremely crucial to use waste from diverse sectors as these materials as they contain silica which renders it as a pozzolanic material.

Palm fiber has been identified as a viable agricultural waste substitute. For the purpose of this research, the ash which is generated as an industrial by-product from the incineration of the fiber has unique features and is a highly reactive material with strong pozzolanic tendencies (Energy Convers. Manag,2017). The palm oil industry has experienced growth as seen from year to year. Processing in the palm oil industry can be classified into crude palm oil and palm kernel oil. The ratio of the amount of oil produced by both products is 30% of the raw material. This means that 70% is palm oil waste (Ishak et al, 2017). The cement industry is also facing serious challenges in terms of the high consumption of electricity as well as very high cost to produce the quantity of cement needed to meet the market requirements. The environmental degradation due to the emission of CO_2 is the main driving force for engineers, scientists, academics and researchers to use alternative materials instead of cement in the concrete production (Hamada et al, 2020). Palm fiber ash has been used to replace cement partially in order to get durable and high strength concrete.

The emission of CO_2 into the atmosphere as a result of cement production causes undesirable environmental impacts which contribute to global warming. Therefore, many studies have been conducted to replace cement partially with suitable supplementary cementitious materials such as palm fiber ash, POFA, fly ash, silica fume, metakaolin and other pozzolanic materials in order to reduce the cement production and mitigate it impacts on the environmental conditions.

Many studies have been conducted to determine the viability of employing ash as a mineral additive in blended cement. Tay (1990) pioneered the use of ash from palm oil mills to replace Portland cement, demonstrating that it has low pozzolanic properties. Many researches later demonstrated that POFA may be utilized as a supplemental cementitious material in mortar or concrete (MegatJohari et al., 2012; Jaturapitakkul et al., 2007; Safiuddin et al., 2011; Sata et al., 2004; Sata, Jaturapitakkul, &Rattanashotinunt, 2010). Palm fiber ash can be used to partially replace Portland cement in concrete, lowering production costs while improving engineering qualities and durability.

Materials and Methods:

a. Materials:

i. Oil palm fiber ash (0.425mm)
ii. Dangote cement (42.5N)
iii. Fine and coarse aggregate
iv. Water
v. Set of sieves
vi. Electric oven
vii. Slump test equipment
viii. Concrete cube mould
ix. Compressive testing machine

Others include: Shovel, scoop, trowel, digital weigh balance and steel measuring tape)

b. Methods: The laboratory methods employed include; **Workability and compressive strength test.**

Composition With Palm Fiber Ash Replacement	**Cement (Kg)**	**Palm Fiber Ash (Kg)**	**Fine Aggregate (Kg)**	**Coarse Aggregate (Kg)**	**Water/Cement Ratio**
0% (control)	10.6920	-	23.760	45.144	0.5
5%	10.1574	0.5346	23.760	45.144	0.5
10%	9.6228	1.0692	23.760	45.144	0.5
15%	9.0882	1.6038	23.760	45.144	0.5

Table 1: Weight of concrete components used for casting

Procedures for conducting slump test

1. Secure the slump cone in place on the base plate.
2. Fill the cone in three layers in a row.
3. A tamping rod is used to tamp each layer 25 times.
4. After the mold has been completely filled with concrete, the top surface is struck off (leveled with the mold top opening) by screening and rolling the temping rod.
5. The cone is gently and carefully lifted vertically once the filling is completed and the concrete is leveled; an unsupported concrete will now sink.
6. The slump is the result of the decrease in height.

The following procedures were carried out as per BS EN 12350 – 2 requirements.

Figure 1: Conduction of slump test

Procedures for conducting compressive strength test

1. Fill the concrete into the molds in three layers, each about 50mm thick.
2. Using a tamping rod, compact each layer with at least 35 strokes each layer (steel bar 16mm diameter and 600 mm long)
3. Using a trowel, level and polish the top surface.
4. Label the cubes for easy identification.
5. The cubes are demolded after being let to set in ambient air for 24 hours.
6. Soak the cubes in the curing tank for 7, 14, or 28 days, depending on their size.
7. After the curing period has passed, remove the cube from the water and brush away any excess water from the surface.
8. Determine the cube's weight.
9. Insert the cube inside the machine in such a way that the load is applied to the cube's opposite sides.
10. Place the specimen in the center of the machine's base plate.
11. Gently rotate the moveable piece so that it touches the specimen's top surface.
12. Apply the weight gradually and continuously without causing any shock.
13. Write out the maximum load that the cube can withstand before it breaks.

Figure 2: Demolding, sampling and curing of concrete cubes

Results and Values:

The test's results, which were achieved using oil palm fiber ash as a partial replacement for cement in the regular concrete mix will be discussed.

Workability and compressive strength tests, in all, were undertaken as two separate experimental procedures. Before testing, the concrete cubes were cured in water for 7, 14, and 28 days.

a. Sieve analysis test result

Sieve Size	Sieve Size (Mm)	Weight Of Empty Sieve (G)	Weight Of Sieve + Soil Sample (G)	Soil Retained (G)	% Retained	Cummulative % Retained	% Finer
4.75	4.75	408.80	410.32	1.52	0.152	0.152	99.848
2.36	2.36	373.79	388.22	14.43	1.443	1.595	98.405
1.18	1.18	346.75	420.97	74.22	7.422	9.017	90.983
600	0.60	327.61	967.62	640.01	64.001	73.018	26.982
425	0.425	300.97	328.43	27.46	2.746	75.764	24.236
300	0.300	324.58	468.72	144.14	14.414	90.178	9.822
150	0.150	311.41	290.35	-21.06	-2.106	88.072	11.928
75	0.075	293.90	234.92	-58.98	-5.898	82.174	17.826
63	0.063	314.47	304.90	-9.57	-0.957	81.217	18.783
Pan		299.35	300.11	0.76	0.076	81.293	18.707

Table 2: Sieve analysis test result

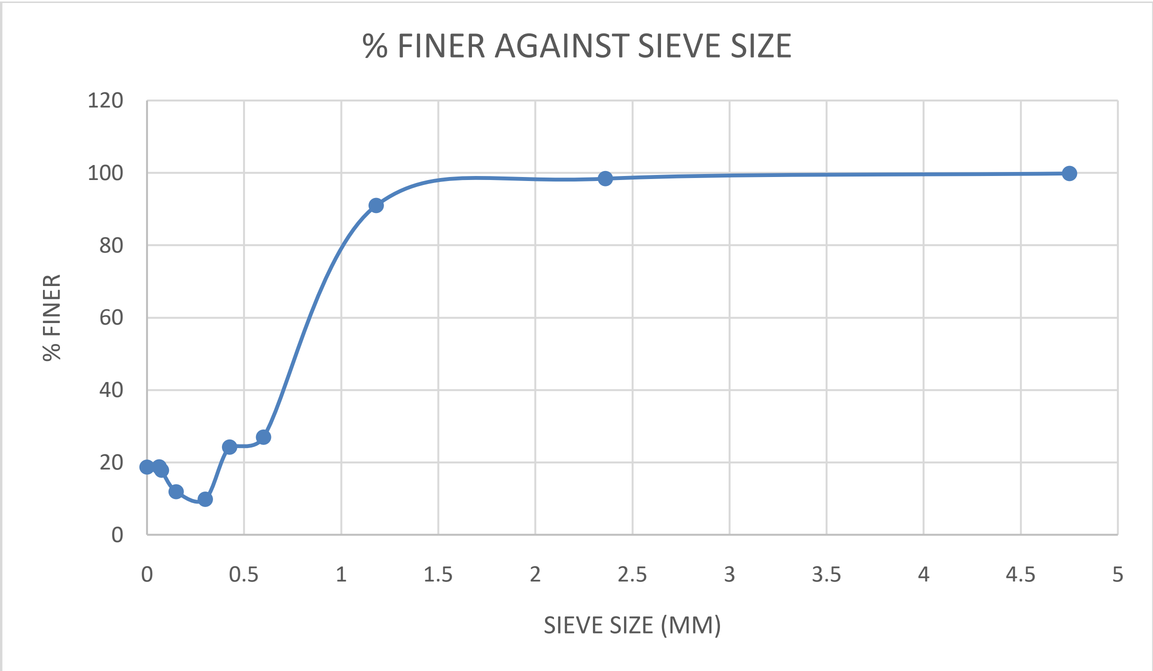

Figure 3: Sieve analysis chart

b. Slump test result

Water-Cement Ratio	Percentage Of Palm Fiber Replaced (%)	Height Of Mould H_1 (Mm)	Height Of Sunken Concrete H_2 (Mm)	Slump $H_1 - H_2$ (Mm)
0.5	0	300	295	5
0.5	5	300	285	15
0.5	10	300	270	30
0.5	15	300	255	45

Table 3: Slump test result values

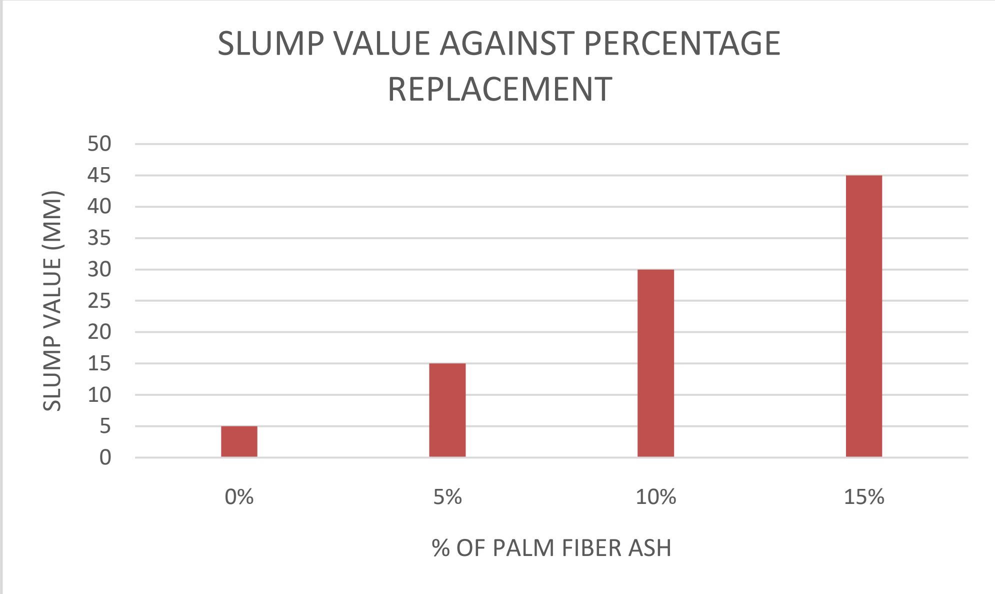

Figure 4: Slump Value Chart

As can be seen in the figure above, the value of the slump increased as the cement was being partially replaced. At 15% which was the highest replacement, more quantity of palm fiber ash was used hence increasing the slump value as shown above. This means that after carrying out the slump test procedures, when the cone was removed, the concrete fell to a height of 255mm. From the figure above, it can also be seen that at 0% replacement the least slump value of 5mm was achieved.

c. Average compressive strength test result

% Palm Fiber Ash	Average Weight (Kg)			Average Applied Load (Kn)			Average Compressive Strength (N/Mm^2)		
	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days
0	7.86	8.01	8.16	252.76	266.11	266.69	11.23	11.83	11.85
5	7.85	7.87	7.96	179.20	187.08	198.65	7.96	8.31	8.83
10	7.82	7.90	8.06	165.21	198.21	233.35	7.34	8.81	10.37
15	8.07	7.96	7.99	181.41	239.95	251.42	8.06	10.66	11.17

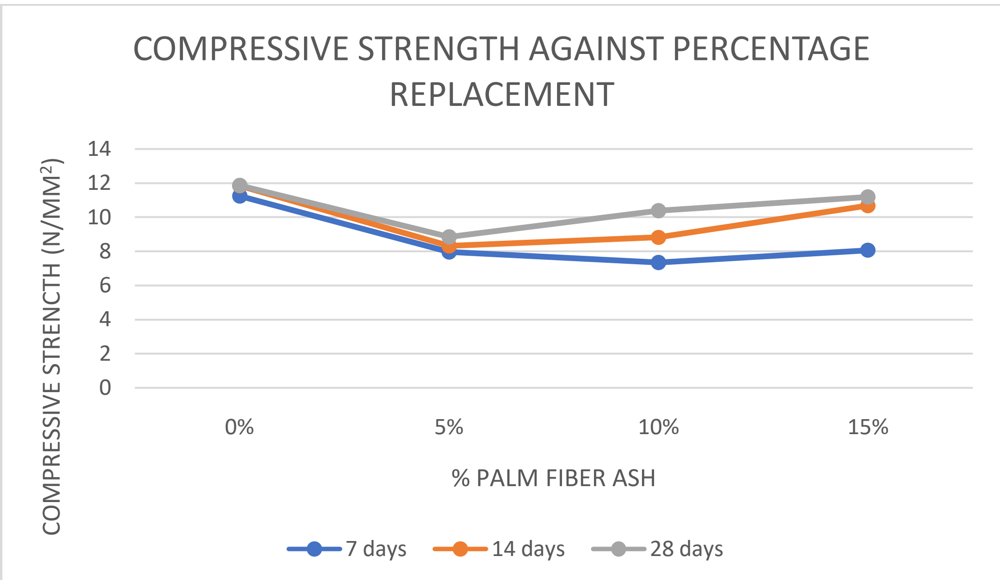

Figure 5: Average compressive strength chart

Comparison of compressive strength

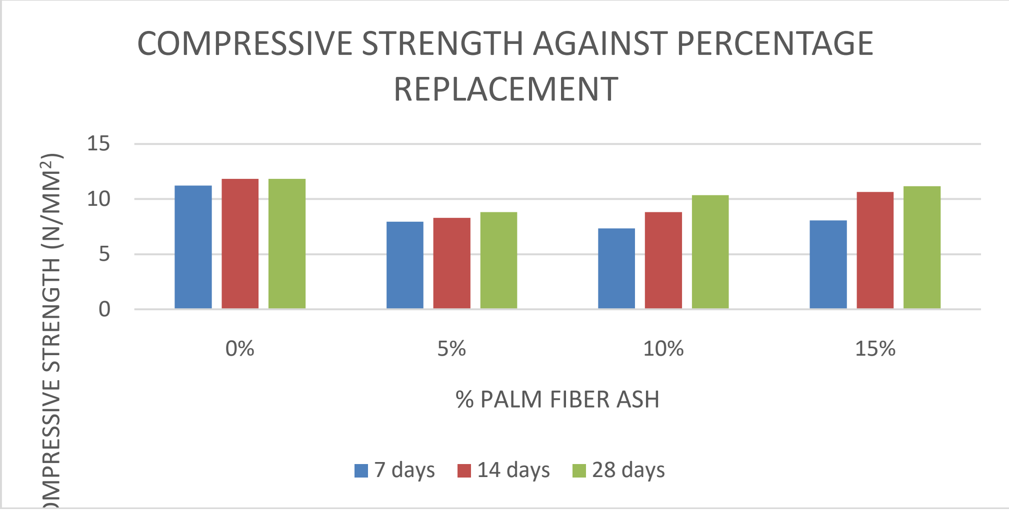

Figure 6: Comparison of compressive strength chart

Figure 4 displays the compression strength development of specimens containing various amounts of palm fiber ash. The control specimens SC were discovered to have achieved an average compressive strength of 11.23 N/mm^2 on day 7, 11.83 N/mm^2 on day 14, and eventually 11.85 N/mm^2 on day 28 representing a strength of 79 percent on the final day of curing.

The compressive strength of concrete cubes that had 5 percent of palm fiber ash in place of cement for 7, 14, and 28 days, respectively, was 7.96 N/mm^2, 8.31 N/mm^2, and 8.83 N/mm^2. The figure makes it evident that there was a drop when compared to the conventional control.

Additionally, concrete cubes containing 10% palm fiber ash displayed a strength drop on day 7, measured at 7.34 N/mm^2, which increased to 8.81 N/mm^2 on day 14, and finally peaked at 10.37 N/mm^2 on day 28.

When compared to the above percentage replacements (5 and 10 percent), the cubes containing 15% of palm fiber ash gave greater values which were given as 8.06N/mm2, 10.66 N/mm^2, and 11.17 N/mm^2 for 7, 14 and 28 days.

Conclusionsand Recommendations:

The concrete slump value considerably increased as a result of the addition of palm fiber ash although the concrete obtained was still very much workable. As a result, it has been amply demonstrated that palm fiber ash is a pozzolanic material that may be used to partially replace cement.

Based on the strength results shown in Table 4.6, palm fiber ash has the potential to be utilized to execute plain cement concrete works, such as bed concrete below wall and column footings, to construct pavements, walkways, and for buildings in regions where high tensile strength is not required.

The fineness of the Palm Fiber Ash should be high in order to achieve a better compressive strength than those of the control concrete.

Thus, the addition of palm fiber ash to concrete helps turn it from a material that raises environmental concerns into a resource for the creation of an effective substitute to cement.

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