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Effect of Palm Tree Leaf Ash on the Compressive Strength of Concrete and its Workability

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ABSTRACT
The effectiveness of palm tree leaf ash as a partial replacement for cement in improving the workability and compressive strength of concrete was investigated. A three factorial experimental design was obtained using the Response Surface Methodology (RSM). Two parameters were varied, which were water/cement ratio which ranged from 0.4 to 0.7and percentage admixture which ranged from 2% to 5% of cement weight to get one response which was the concrete compressive strength. A concrete design mix of 1:2:4 was adopted. Sieve analysis was done to determine the suitability of the fine and coarse aggregates to be used. Fresh concrete was tested for its workability and a total of 36 cubes were produced, 4 cubes for each run order. For each run order, 2 cubes were cured for 14 days while the remaining 2 were cured for 28 days. The compressive strength of each concrete was obtained and subjected to response surface analysis. Analysis of data showed that an increase in the admixture from 2% to 5% led to an increase in workability from 50mmto 55mm. Optimum strength of 15.755 N/mm^{2}was obtained onday 14 while it was 17.699 N/mm^{2}on day 28 using 5% admixture and 0.55 water/cement ratio. A compressive strength model was generated with R^2value of 0.67 for 14 days and 0.74 for 28 days. These results show that palm tree leaf ash can be used as a partial replacement of cement at 5% partial replacement.

KEYWORDS: *Palm tree, Ash, Concrete, Compressive strength, Admixture, Cement*

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I. INTRODUCTION

Research and advancement of construction materials in civil engineering have been tending towards finding a concise positive solution for material availability, its effects on the environment as well as cost. This has led to the discovery of partial replacement for some construction materials. For example, gravel has been partially replaced with periwinkle shell or palm nut shell, sand with finely grinded glass waste, cement with rice husk or groundnut shell ash, etc. The benefits of these partial replacements include light weight, low cost, reduction in environmental pollution, good quality, high strength, durable and highly compact structure, etc.[1]. According to[2], water resisting concrete incorporate fine particle cement replacements and are impermeable to water and other fluids.

Concrete is used majorly for its ease of placement and molding.Its component materials are widely available and are also quite low in cost but most importantly, it possesses good compressive strength and can also overcome some extent of tensile stress when prestressed. In general, concrete is a material that forms the basis of our modern life[3].The concrete strength is assessed by measuring the crushing strength of cubes or cylinders of concrete made from the mix which is then cured and tested according to standard procedures[4]. During the process of hydration, when water combines with a cementitious material, a cement paste is formed which fills void spaces, increase workability and bonds the aggregate together [5]. The pore structure of concrete contributes to the concrete durability. A characterization of this pore structure is done by a simple test to determine concrete durability[6]. Although concrete has a lot of advantages, there are some negative traits of concrete such as being porous as it hardens as well as being brittle and low in tensile stress. All these must be accounted for by engineers.

In the production of concrete, the component material which is more expensive than others is the cement, making it needful to find a partial replacement for cement without negatively affecting its binding nature and other characteristics by the consideration of admixtures.Due to the importance of concrete,the selection of its partial replacement must consider the long term effect on the concrete performance, durability in the structure and its effect on the environment[7].Admixtures are used to modify the properties of concrete component material. Admixtures are materials other than water, aggregate, andcement, used as an ingredient of concrete or mortar and added to the batch immediately before or during its mixing, to modify one or more of the properties of concrete in the plastic or hardened state[8]. There are different categories of chemical admixtures such as air entrainers, water reducers, set retarders, super plasticizers, and set accelerators which shorten setting time of concrete[9].These materials are essential product that can serve as good Pozzolans, which are materials with an amorphous siliceous or siliceous and aluminous content that react with calcium hydroxide in the presence of water to form cementitious hydration products[10].These admixtures have different effect on fresh concrete and also on hardened concrete[8].

The production of palm oil in Nigeria is a very lucrative business, but the processes involved produce wastes of various forms[11]. Oil palm leaf is one the wastes of palm tree cultivation. Since Nigeria is currently the fifth largest producer of oil palm in the world after Indonesia, Malaysia, Thailand and Colombia with an annual production volume of 850,000 tonnes[12], this waste will be enormous. In Malaysia, oil palm fronds and trunks used to be burned but environmental concerns led to banning of the practice in the 1990s. Now they are usually left on the ground to rot and decompose, thereby fertilizing the soil[13].In the same vein, the use of palm tree ash as a partial replacement for cement would be a welcomed development in Nigeria as it will reduce the waste load on the environment. The chemical composition of palm tree leaf ash makes it a viable option. Table 1 shows a report of the chemical composition of palm tree leaf ash and cement.

Table 1: Chemical composition of palm tree leaf ash

Chemical Composition	Percent by weight	
	Palm tree leaf ash	Cement
SiO_2	45.22	19.53
Al_2O_3	4.77	6.0
Fe_2O_3	5.9	4.0
CaO	22.76	62.0
MgO	0.98	1.40
Na_2O	0.69	0.50
K_2O	1.99	0.62
T_1O_2	0.15	0.37
LOI	15.0	2.0

Source:[14]

II. MATERIALS AND METHODS

2.1. Mix Design of Concrete

The Response Surface Model (RSM) was adopted for mix design of concrete. RSM is a statistical tool that explores the relationship between several explanatory variables and one or more response variables.

2.2. Materials

The materials used in this work are the palm tree leaf ash, river sand, ordinary Portland cement, gravel and water.

2.3. Palm Tree Leaf Ash Production

The palm tree leaf used was collected from a local farm at Owerri west L.G.A, Imo State. The palm tree leaf was burnt openly in a cylindrical steel container and crushed to ashes to make the aggregate very fine.

2.4. Particle Size Distribution Test

The obtained aggregate was subjected to sieve analysis according to BS 812 part 103:1 of 1985. Various sizes of sieves were used as specified by the BS code. The distribution of different grain size determines the engineering properties of an aggregate.

2.5. Concrete Moulding

Concrete moulding was done according to the design mix gotten from the RSM.Batching operation used was by mass. A nominal mix design of 1:2:4 (cement: sand: concrete) was initiated also. The mould used was of dimension 150mm by 150mm by 150mm. Two factors were varied in the concrete mix, the water/cement ratio and the percentage of cement replacement by admixture.

2.6. Slump Test

The essence of slump test is to analyze theworkability of fresh concrete mixas well as get the best mix.The value of slump varies from concrete to concrete depending on its usage[15].

2.7. Water Absorption Test

Water absorption rate of a concrete depends on the pores present in the concrete. This test was carried out to determine the rate of absorption of water by the concrete, through measuring the increase in mass of the concrete every 4 days after immersing in water for 14 days and 28 days. The rate of water absorption was measured in percentage as a function of time.

2.8. Test for Compressive Strength

The concrete was moulded in accordance to BS-1881-Part-116-83. The moulded concrete cubes were left for 24 hours to set before demoulding and curing by full immersion to increase the strength of the concrete, promote hydration, eliminate shrinkage and absorb heat of hydration until the day of test. The run order generated by the RSM was 9 in number, 4 cubes were prepared for each, 2 to be cured for 14 days and 2 for 28 days. Before crushing the cubes, they were brought out of the tank, weighed and then air dried for 2 hours. The compressive strengths of the cubes were tested in accordance to BS-1881-Part-116-83 using universal testing machine.

2.9. Experimental Design

A three factorial experimental design was obtained using the RSM (Table 2). Water/cement ratio was varied from 0.4 – 0.7[16], admixture was added to the cement in percentages ranging from 2% - 5%, other materials like sand and gravel were kept constant. A design mix of 1:2:4 was used for the concrete mixture[17].

Table 2: Design of Experiment

Observation	Sort order	Run order	Repetition	Water/Cement ratio(%)	Admixture ratio(%)
Obs1	1	1	1	0.4	0.02
Obs2	2	2	1	0.55	0.02
Obs3	3	3	1	0.7	0.02
Obs4	4	4	1	0.4	0.035
Obs5	5	5	1	0.55	0.035
Obs6	6	6	1	0.7	0.035
Obs7	7	7	1	0.4	0.05
Obs8	8	8	1	0.55	0.05
Obs9	9	9	1	0.7	0.05

III. RESULT AND DISCUSSION

3.1. Particle Distribution Test

The particle size distribution of the river sand and gravel used are shown in Tables 3 and 4 and Figures 1 and 2. The results show that the sand is good for concreting and the gravel is a 19mm to 20mm gravel.From the results, concrete mix was computed as follows: volume of concrete cube = 0.003375m^3, density of concrete = 2400kg/m^3 (constant), and mass of concrete cube = 8.1kg.

Table 3: Sieve analysis of river sand

Sieve Size(mm)	Mass Retained (g)	% On Sieve	% Retained	% Passing	Zone-2 Limits
5.00	3	0.6	0.6	99.4	100
4.75	3	0.6	1.2	98.8	90-100
2.36	15	3	4.2	95.8	75-100
1.18	241	48.2	52.4	47.6	55-90
0.60	164	32.8	85.2	14.8	35-59
0.21	71	14.2	99.4	0.6	0-10
Tray	3	0.6	100	0	-

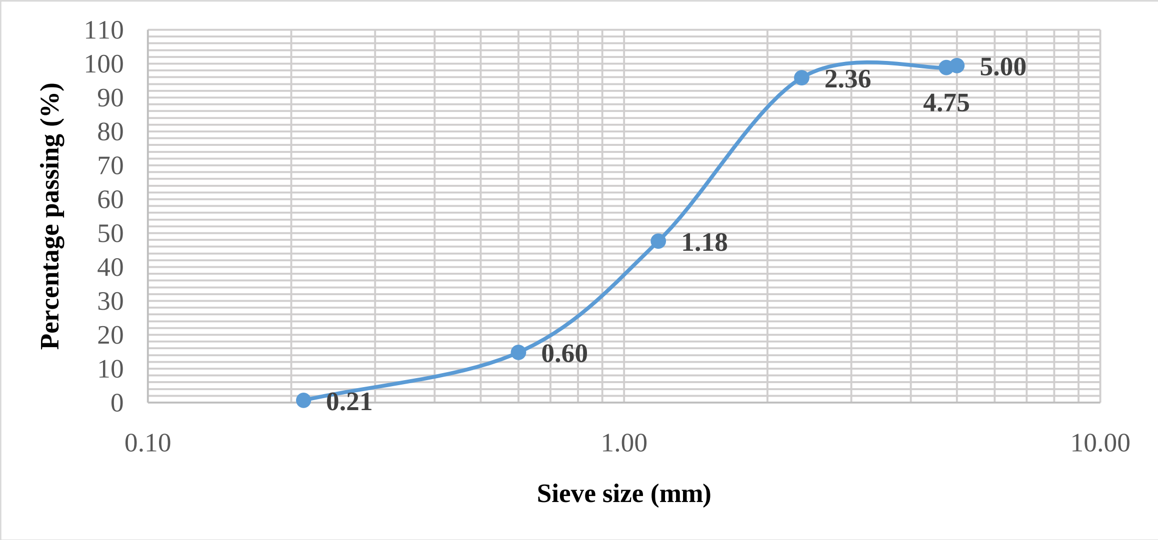

Fig.1: Particle size distribution curve of sand

Table 4: Sieve analysis of gravel

Sieve Size (mm)	Mass Retained (g)	% On Sieve	% Retained	% Passing
50.00	0	0	0	100
37.50	0	0	0	100
25.00	114	11.4	11.4	88.6
19.00	785	78.5	89.9	10.1
13.20	89	8.9	98.8	1.2
9.50	12	1.2	100	0
Tray	0	0	100	0

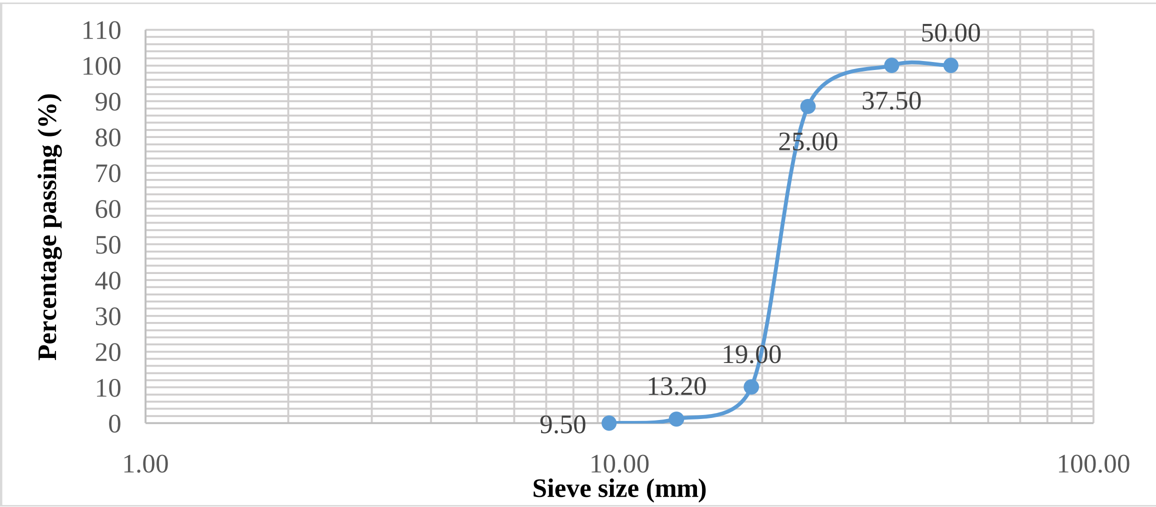

Fig. 2: Particle size distribution curve of gravel

3.2. Slump Test

The slump test result is presented in Table 5. The test was done on all 9 runs to determine the workability of the concrete with different mix proportions and admixtures. The result shows that the higher the admixture, the higher the slump (workability) which is helpful when carrying out construction activities insitu.

Table 5: Slump test result

Run Order	% Admixture	Water/Cement Ratio	Slump Value (mm)
1	0.02	0.4	0
2	0.02	0.55	26
3	0.02	0.7	50
4	0.035	0.4	0
5	0.035	0.55	27.5

6	0.035	0.7	54
7	0.05	0.4	0
8	0.05	0.55	28.5
9	0.05	0.7	55

3.3. Water Absorption Test

The water absorption test was done every four days until the curing age was complete on days 14 and 28, respectively. Tables 6and 7 summarize the results of the rate of water absorption for the concrete during the curing days. The values under each run order are the mass (kg) of each concrete cube as it absorbs water daily due to the curing process. From the results, it can be observed thatwater absorption is maximum from day 14. Run order 1 with 2% admixture and 0.4 water cement ratio (which is the lowest admixture) gave the lowest absorption and not so good compressive strength. But an increment in the admixture (to 5%) led to a more moderate water absorptionand increase in compressive strength of the concrete. This is because as water is absorbed, the chemical reactions occurring within the concrete mix progresses which is vital for concrete strength.

Table 6: Average values of water absorption in kgfor all run orders for 14 days

Day	Run order 1 Mass(kg)	Run order 2 Mass(kg)	Run order 3 Mass(kg)	Run order 4 Mass(kg)	Run order 5 Mass(kg)	Run order 6 Mass(kg)	Run order 7 Mass(kg)	Run order 8 Mass(kg)	Run order 9 Mass(kg)
0	8.114	7.531	7.149	7.858	7.910	7.638	7.603	7.563	7.929
4	8.178	7.604	7.204	7.919	7.972	7.692	7.667	7.619	7.999
8	8.189	7.617	7.216	7.931	7.984	7.702	7.680	7.626	8.009
12	8.184	7.610	7.210	7.925	7.977	7.697	7.674	7.623	8.004
14	8.189	7.617	7.215	7.929	7.984	7.703	7.681	7.627	8.009

Table 7: Average values of water absorption in kg for all run orders for 28 days

Day	Run order 1 Mass(kg)	Run order 2 Mass(kg)	Run order 3 Mass(kg)	Run order 4 Mass(kg)	Run order 5 Mass(kg)	Run order 6 Mass(kg)	Run order 7 Mass(kg)	Run order 8 Mass(kg)	Run order 9 Mass(kg)
0	7.941	8.076	7.436	7.784	7.790	7.410	7.442	7.713	7.473
4	7.979	8.147	7.502	7.843	7.854	7.468	7.498	7.769	7.529
8	7.992	8.156	7.511	7.850	7.860	7.475	7.510	7.776	7.536
12	7.993	8.156	7.511	7.849	7.862	7.475	7.508	7.777	7.537
16	7.994	8.157	7.511	7.850	7.862	7.476	7.511	7.779	7.539
20	7.995	8.158	7.512	7.852	7.864	7.478	7.513	7.780	7.539
24	7.997	8.159	7.512	7.847	7.863	7.478	7.512	7.781	7.540
28	7.946	8.129	7.478	7.811	7.832	7.446	7.468	7.749	7.502

3.4. Concrete Compressive Strength

Figures 3 and 4show the optimal concrete compressive strength and the corresponding ratio of cement to water and admixture for 14 days curing.It is observed that the compressive strength of the concrete increases with increasing water/cement ratio till it gets to a turning point which is the optimal point and begins to decrease as water/cement ratio exceeds the turning point.A similar trend is observed in Figure 4 where the admixture replacement percentage was seen to improve the compressive strength until an optimal point was reached. An optimal strength of 15.755N/mm^2 was attained at a water/cement ratio of 0.49 while an optimal strength of 15.635N/mm^2 was achieved at an admixture ratio of 3.3%.

Figures 5 and 6 present the optimal concrete compressive strength and the corresponding ratio of cement to water and admixture for 28 days curing.It is also observed that the compressive strength of the concrete increases with increasing water/cement ratio till it gets to the optimal point and begins to decrease as water/cement ratio increases beyond this point. However, it is observed in Figure 6 that the admixture improves the compressive strength up to 5% replacement.An optimal strength of 14.609N/mm^2 was attained at a water/cement ratio of 0.537,while an optimal strength of 17.699N/mm^2 was achieved at an admixture ratio of 5%. Theseresults show that as curing age increases from 14 days to 28 days, the percentage of cement replaceable by palm tree leaf ash also increases.

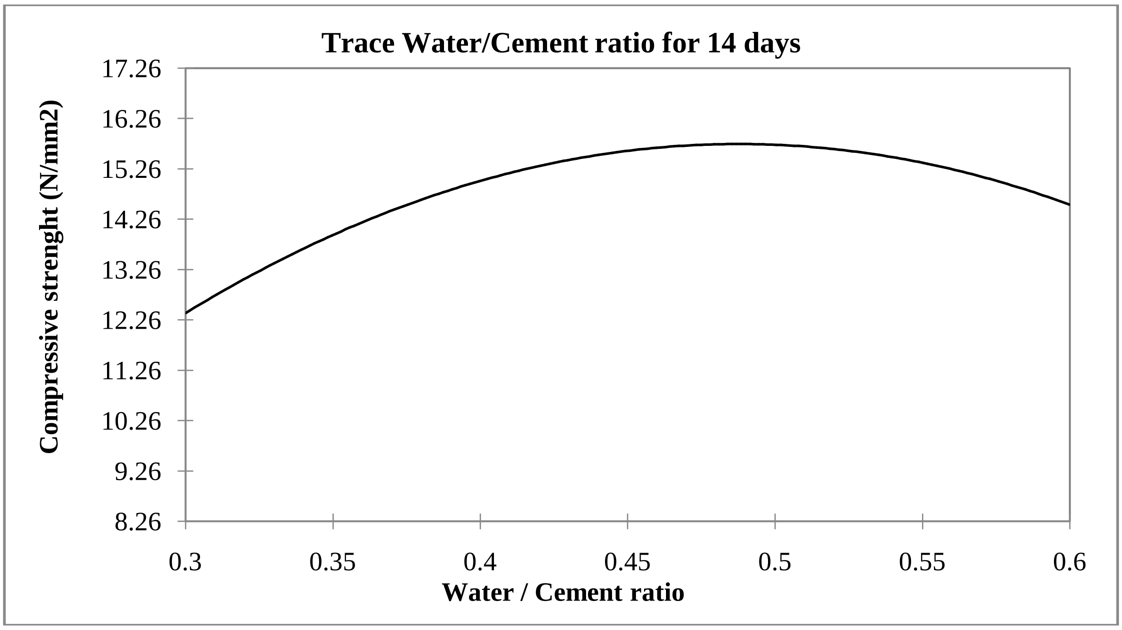

Fig.3: Compressive strength against water/cement ratio for 14 days

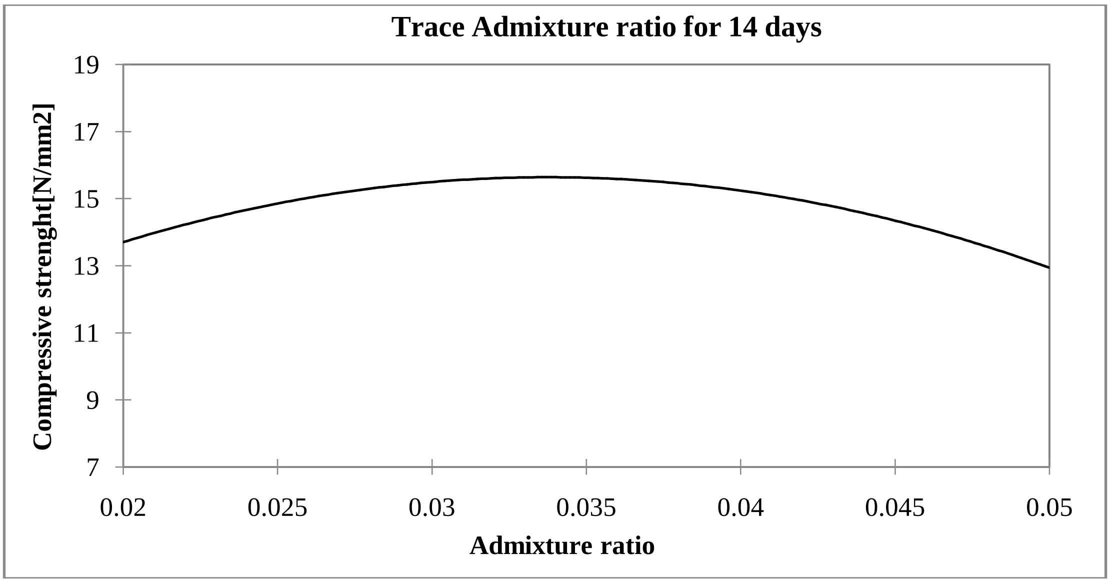

Fig.4: Compressive strength against admixture ratio for 14 days

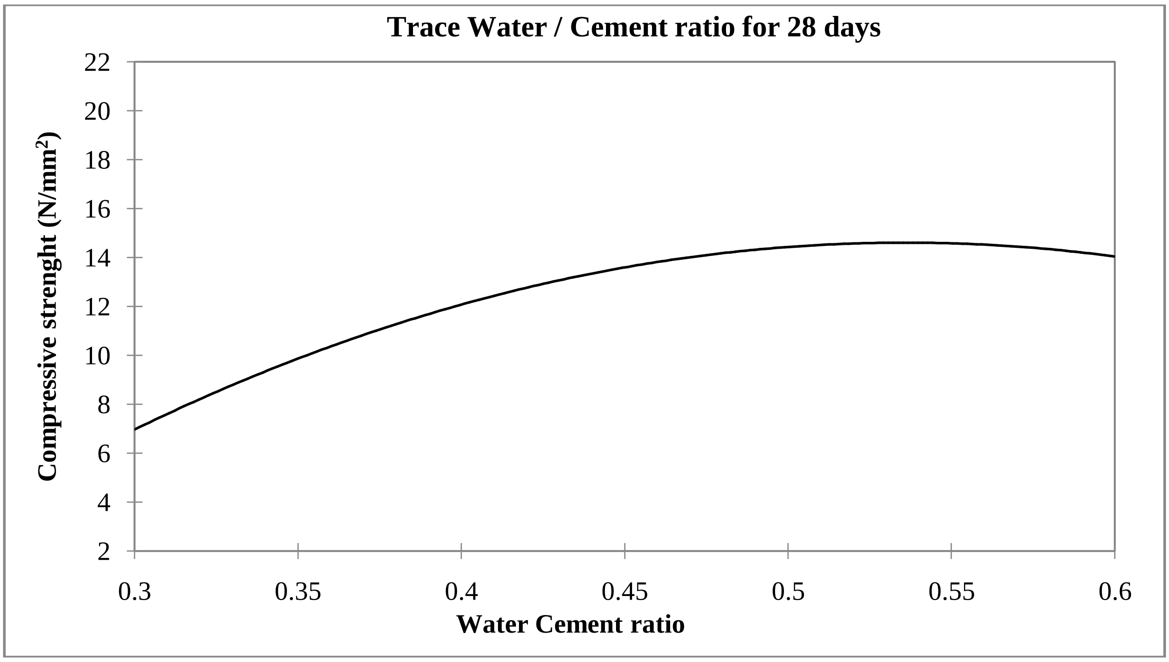

Fig. 5: Compressive strength against water/cement ratio for 28 days

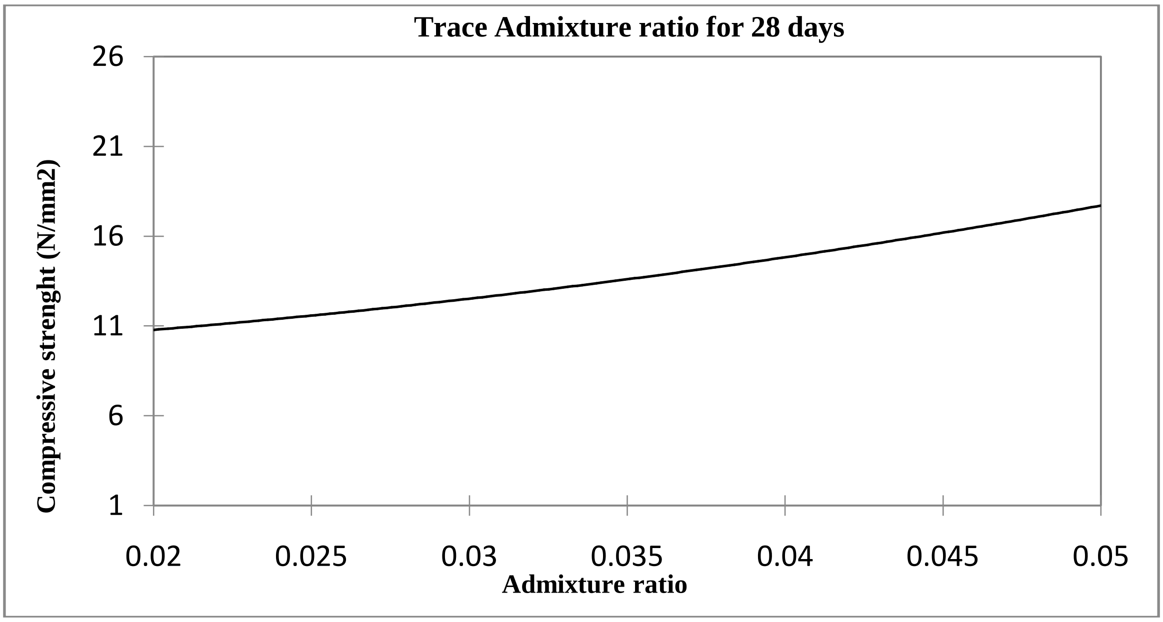

Fig. 6: Compressive strength against admixture ratio for 28 days

Figures7 and 8 give the contour plot combining the compressive strength, admixture and water/cement showing different ratios and what point gives the maximum strength of concrete for 14- and 28-days curing, respectively.From the Figures the admixture and water/cement ratio with the highest compressive strength can be easily obtained using the legends.The different colors show the increasing range of compressive strength. Figure 7 shows the maximum range of compressive strength to be achieved after 14 days of curing lies between 14.8556 and 15.7974 N/mm^2. Figure 8 shows the maximum range of compressive strength to be achieved after 28 days of curing lies between 17.2 and 19.1 N/mm^2. Consequently, palm tree leaf ash can be considered a suitable replacement of cement in constructions where the concrete members can be cured for longer time periods.

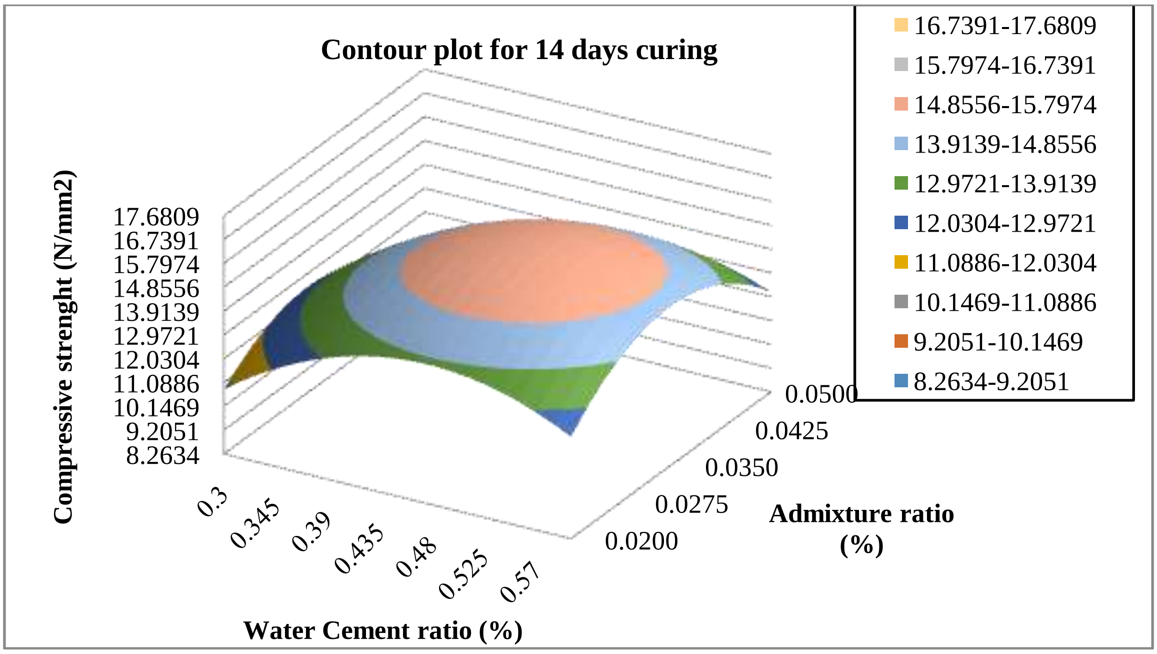

Fig.7: 3D view response surface showing the contour plot of compressive strength against water/cement ratio and admixture ratio for 14 days

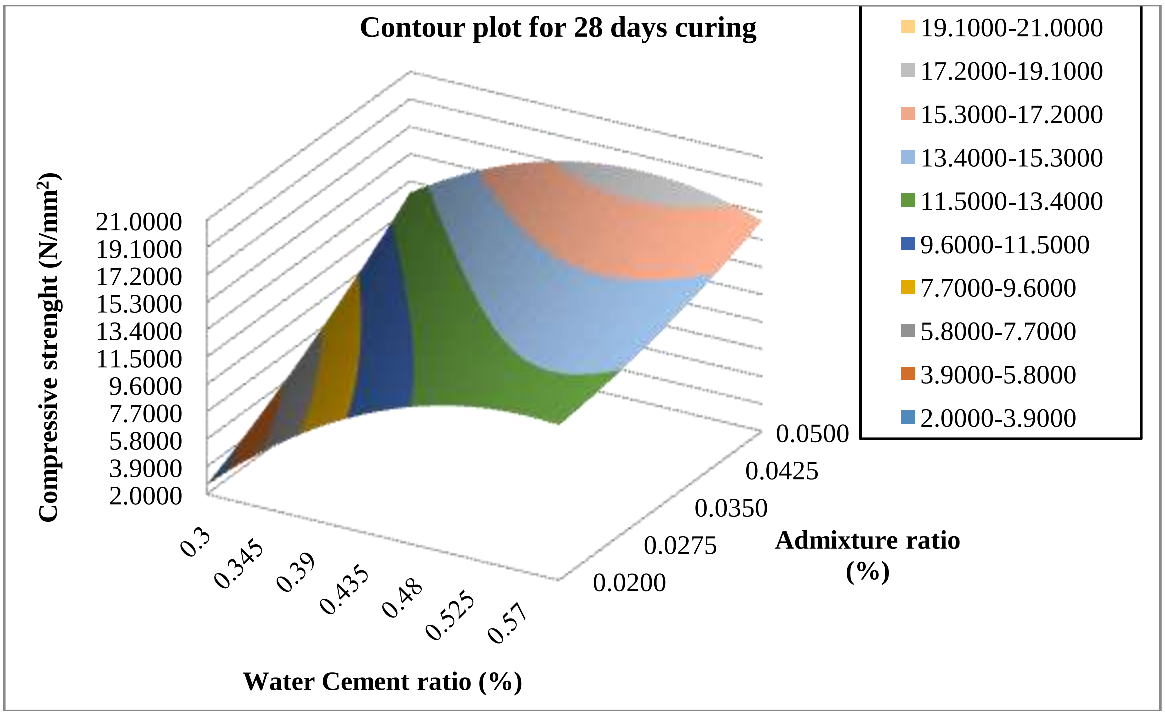

Fig. 8: 3D view response surface showing the contour plot of compressive strength against water/cement ratio and admixture ratio for 28 days

3.5. Response Surface Model Development

Equation (1) is the general response surface model generated based on the various compressive strengths.

$$Y=\beta_0 + \beta_1x_1 + \beta_2x_2 + \beta_3x_1^2 + \beta_4x_2^2 + \beta_{12}x_1x_2 \quad (1)$$

where Y = compressive strength, β_0=constant which represents the mean of the response, β_i=constants which estimates the main effects of the factors (x_i)on the response, β_{ij}=two factor interactions, and x_1 =water cement ratio, x_2= admixture.

Hence, Equation (2) gives the specific model for 14 days curing while Equation (3) is the specific model for 28 days curing.

$$Y = 15.62030 + 1.07761*x_1- 0.3828*x_2 - 2.1468*x_1^2 - 2.3013*x_2^2 - 0.3428*x_1x_2 \quad (2)$$

$Y = 13.5982 + 3.5363*x_1 + 3.4583*x_2 - 3.0910*x_1^2 + 0.6425*x_2^2 - 1.5243*x_1x_2$ (3)

Equations 2 and 3 can be used to estimate the compressive strength of concrete when cured for 14 days and 28 days respectively when palm tree leaf ash is used as the admixture.

IV. CONCLUSION

The effectiveness of palm tree leaf ash as a partial replacement for cement has been studied. From the results obtained, the workability of concrete can be increased by partially replacing cement with palm tree leaf ash. An increase in the admixture from 2% to 5% led to an increase in workability from 50mm to 55mm. In addition, concrete curing is a vital process that can enhance concrete compressive strength. An increase in concrete compressive strength of 1.944 N/mm^2 (from 15.755 $N/mm^2$to 17.699N/mm^2) was observed with an increase in the curing age from 14 to 28 days.Therefore, it is concluded that palm tree leaf ash can be used as a supplement for cement, and such usage has the additional benefit of removing palm tree leaves from the waste stream.

REFERENCES

[1]. Dayalan, J., Beulah, M., "Effect of Waste Materials in Partial Replacement of Cement Fine Aggregate and Course Aggregate in Concrete," International Journal of Inventive Engineering and Sciences (IJIES), vol. 2, no. 4:2319-9598, March 2014:

[2]. Dave, B., "Concrete that fears water no more," Building design + construction, 12 1 2007. Retrieved from www.concretecenter.com/performance-sustainability-(1)/special-concrete/water-resistant-concrete.aspx.

[3]. Mehta, P., Monteiro, P.,, Concrete Microstructure, Properties, and Materials., third edition ed., Prentice hall, Inc. McGraw-HillNew York Chicago San Francisco Lisbon London MadridMexico City Milan New Delhi San Juan Seoul Singapore Sydney Toronto. 2005.

[4]. Bill, M., John, B., and Ray, H., reinforced concrete design, london: macmillian education limited, 2014.

[5]. Gibbons, J., "measuring water in concrete," concrete construction, 1 october 2012. www.Concreteconstruction.net

[6]. De Schutter G. and Audenaert K., "Evaluation of water absorption of concrete as a measure for resistance against carbonation and chloride migration,Springer " vol. 37, no. 591, 27 november 2004. doi:http://doi.org/10.1007/BF12483288

[7]. Hashim, H.B., "the effect of oil palm fibre on concrete properties," University of Technology Malaysia, Civil Engineering. 2008.

[8]. Harit, A. K., "Guidelines on the use of Admixtures in concrete bridges and structues, Indian railways, research designs and standard organisation.," 1999. Retrieved from www.rdso.indianrailways.gov.in: www.rdso.indianrailways.gov.in

[9]. Gopal, M., "theconstructor.org", 7 march 2011. [Online]. Available:theconstructor.org/concrete/types-of-concrete-admixture/5558/amp/.

[10]. Walker, R., Pavia, S., " Physical properties and reactivity of pozzolans, and their influence on the properties of lime - Pozzolan pastes.springer.com," 20 november 2010. [Online]. Available: https://link.springer.com/article/10.1617/s11527-010-9689-2.

[11]. Chinedu, I.O., "www.aweimagazine.com," 11 december 2011. [Online]. Available: www.aweimagazine.com/article/palm-oil-milling-the-impact-34.

[12]. Anyanwu, C.N., Ibeto, C.N., Eze, I.S. and Ezeoha, S.L., "present and prospective energy use potentials of selected agricultural wastes in nigeria," renewable and sustainable energy, pp. 5-7, 4 june 2013.

[13]. Heuze, V., Tran, G., Sauvant, D., Lebas, F., "Oil palm fronds and oil palm crop residues. feedipedia, a programme by INRA, CIRAD, AFZ and FAO ","www.feedipedia.org," 25 june 2015. [Online]. Available: www.feedipedia.org/node/6916.

[14]. Iorliam, A. Y., Agbede, I. O. and Jeiyol T,, "Effect of Palmyra palm leas ash on cement stabilization of Makurdi shale.," Leonardo Electronic Journal of Practices and Technologies, vol. 11, no. 20, pp. 193-205, 2012.

[15]. Emesiobi, F.C., testing and quality control of materials in civil and highway engineering, port harcourt, rivers: goodnews printing press, 2000, p. 291.

[16]. Jeff, G., "The importance of water/cement ratio in concrete countertop mix design," The concrete countertop institute, 11 July 2011.

[17]. Kazeem, K.A., Wasiu, O.A., Idris A.A., "Determination of appropriate mix ratios for concrete grades using Nigerian portland-limestone grades 32.5 and 42.5," leonardo Electronic Journal of Practice and Technology, no. 26, pp. 79-88, January-June 2015.

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