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Performance Evaluation of Calcined Termite Mound (CTM) Concrete with Sikament NN as Superplasticizer and Water Reducing Agent

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ABSTRACT
In this research,5, 10 and 15 % calcined termite mound (CTM) was used to replace cement by weight. A superplasticizer and water reducing agent Sikament NN was administered as an additive. For every percentage level of CTM replacing cement, Sikament NN was added by 1.0, 1.5, 2.0, 2.5 and 3.0 % by weight of cement and water content of the mix is reduced by 20 % as specified by the manufacturers of Sikament NN. Upon the replacement of cement with CTM the consistency result obtained for normal consistency is 32.5% for the reference mix, 33.5, 34.8 and 36.2 % for 5%, 10 and 15 % replacement of cement wit CTM respectively, while the setting time was accelerated for all replacement levels. The compressive strength of mixes having 5 and 10 % CTM replacing cement shows strength improvement of 7.6 % and 13.3 % respectively above the reference mix after 90 days, while 15 % replacement recorded a compressive strength reduction of 4.4 % for the same period. As the Sikament NN is being administered, workability reduced significantly at the early stage of administration, but at later stages the slumps improves and collapsing at later stages. However, improved compressive strengths were recorded with respect to the reference mix upon the administration of Sikament NN, 23.4, 20.3 and 13.7 % compressive strength improvement was recorded respectively for 5, 10 and 15 % replacement of cement with CTM.

Keywords: *Calcined Termite Mound, Compressive Strength, Consistency, Sikament NN, Workability.*

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I. INTRODUCTION

The role concrete plays in our modern society can be found in structures such as buildings, roads, bridges, dams etc. The ease with which it can be formed into different sizes and shapes makes it a popular and widely patronized construction material. The correct proportion of raw materials, mixing, placement and curing are needed in order to obtain concrete with optimum properties[1].

Several studies utilizing industrial and agricultural wastes in concrete production have been carried out. This isgeared towards reducing environmental pollution that may arise as a result of too many wastes thereby reducingthe cost of concrete production and the possibility of a concrete with superior qualities [2]. This process minimizes greenhouse gas emission and energy consumption associated with production of cement. Likewise natural soils and clays have been used in natural or modified state for concrete production with advantages of reduced environmental pollution and cost.

Termite mounds are heaped pileof earth built by termites and are distributed all over the world from 47^o Northern latitude to 47^o Southern latitude. They are extremely abundant in the tropical rain forest. The nature of the termite mound properties depends on the complexity of the social organization of the termites, diet, biology and environmental factors on the site. The are two types of termites are the wood dwelling termites that lives in fresh or dead wood in which also they build their nests and the subterranean termites that lives in soil which is connected with the ground and its necessary for the normal life and dwelling of the colony[3].

The nest of the subterranean termites are certainly the most admired natural structures that can reach 6 m in height and 4 m wide at the base, but towers built by some of the African Macrotermes species can be even up to 9 m high [3].

Study by [4] shows that calcining the termite mound material, grinding it into fine form and using it to partially replace cement produces concrete with compressive strength greater than the reference mix.

Studies by [5], [4] and [6] shows that the CTM requires more water content to attain a standard consistency, which means the material has affinity for water. But water is known to leave voids in concrete after evaporation when hydration is complete thereby making the concrete to absorb more water thereby jeopardizing its density and compressive strength.Secondly CTM has proven to improve the flexural strength more than the compressive

strength. Introducing Sikament NN is aimed at reducing the water content by 20 % but attaining the required workability with improved strength.
In this regard, this research is aimed at replacing cement with CTM at 5, 10 and 15 % by weight of cement, while Sikament NN is administered on every replacement of cement with CTM in the range of 1.0, 1.5, 2.0, 2.5 and 3.0 % by weight of cement.

II. REVIEW OF RELATED LITERATURE

2.1 Supplementary Cementitious Materials

The effect of partially replacing Portland cement with calcined kaolin in mortar and concrete production on compressive strength as well as on durability characteristics of mortar and concrete mixes pertinent to coastal environments. Findings shows the possibility of replacing cement with calcined kaolin by up to 30 % by weight with associated strength gain [7].
A natural pozzolan (volcanic turf) obtained from Turkey found to be a class N pozzolan according to ASTM C618-03 was used to place cement at various percentages and the compressive strength determined. From the study it was found that there is a maximum pozzolan content that can be used with an optimum productivity and efficiency to achieve maximum strength. The optimum pozzolan/cement ratio for maximum strength is approximately 0.28, with a decreasing efficiency as the ratio decreases. For equal amounts of pozzolan used, the mix with the highest amount of cement has the highest efficiency of pozzolan [8].

2.2 Termite Mound as Supplementary Cementitious Materials

The effect of calcined termite mound material (TMM) on the compressive strength of concrete was carried out by [4]. Setting times test conducted on CTM shows that addition of the material considerably increases the initial and final setting times indicating that the CTM is an accelerator and recommended for cold weather concreting.Its effect on fresh concrete shows that at 40% replacement, the heat of hydration is reduced by 17%. The properties of the hardened concrete indicates that CTM increases the flexural strength more than the tensile strength. The compressive strength decreased as the CTM content increased, while compressive strength of mortar shows gradual increase in compressive strength as curing period proceeded above 60 days. The mortar compressive strength at 10% replacement of cement was above that of the reference mix showing conformity with pozzolanic behaviour.
TMM randomly selected from some habitats of a common tropical specie of termites from Iyeke-Ogba area of Edo state, Nigeria was investigated by [9]. The result of the geotechnical properties of the mound soil showed that mound soil belongs to class SC (Silty Clay) using the Unified Soil Classification System (USCS).A maximum compressive strength of 47.78 N/mm^2 with 24mm slump was attained by the addition of 15% TMM, giving 21.83% increase in the compressive strength and 36.92% improvement on workability and concludes that TMM can be used in construction as an additive in concrete but should not exceed 15%.
Oxide composition testresult shows the material is a good pozzolana as it exhibits good pozzolanic properties [6].The results indicates that the addition of TMM considerably advanced the initial and final setting time of cement base paste and collaborates findings by Elinwa (2006). As the percentage substitution of cement with TMM increases, the initial and final setting time decreased. At 30% substitution level, the initial setting time reduced by 84.6% while the final setting time advanced by 30.19% with these results, it could be opined that TMM is very effective cement setting time accelerator.

III. MATERIALS

The materials used for the study are cement, coarse and fine aggregates, calcined termite mound material (CTM), water and Sikament NN.
The cement used for this work is Ashaka brand of portland cement with a specific gravity of 3.15 and conforms to BS EN 196(2000) specifications.
The coarse aggregate used for this work was obtained from local suppliers in Bauchi, Bauchi State, Nigeria. It is a normal weight aggregate from igneous sources with nominal size of 20 mm, specific gravity of 2.63, bulk density of 1485 kg/m^3, aggregate crushing value (ACV) of 15.52% moisture content of 0.56%.
The fine aggregate (sand) was sourced from local suppliers in Bauchi with a specific gravity of 2.64, bulk density of 1528 kg/m^3 and moisture content of 0.42%. Potable tap water fit for drinking obtained from Abubakar Tafawa Balewa University, Bauchi was used for the work, no test was conducted on the water.
Termites mound clay soil was obtained from Federal Polytechnic Bauchi, in the Northern part of Nigeria. The mound soil was calcined to a temperature of approximately 800^{0}C for a period of one hour using kerosene fueled kiln at the Industrial Design Department of Abubakar Tafawa Balewa University, Bauchi. The sample was allowed to cool for about 24 hours before grinding to a fine textureusing the mechanical grinder and sieved through 150µm sieve size. The resulting product is referred to as calcined termite mound (CTM).

The physical properties namely moisture content, specific gravity, liquid limit, plastic limit and plasticity index of the CTM were determined. Test results are shown in Table 1 and conforms to EN 1097-6 BS EN ISO 17892.

Table 1: Physical Properties of CTM

Parameter (Unit)	Value
Moisture Content (%)	16.35
Specific Gravity	2.53
Liquid Limit (%)	28.00
Plastic Limit (%)	0.00
Plasticity Index (%)	28.00

Table 2: Oxide Composition of CTM

Parameters	Value (%)
SiO_2	67.74
Al_2O_3	14.23
Fe_2O_3	5.15
CaO	1.79
MgO	0.59
SO_3	0.04
K_2O	4.12
Na_2O	0.23
P_2O_5	0.06
MnO_3	0.07
TiO_2	1.05
LOI	3.93

Oxide composition was determined using X-Ray Fluorescence (XRF) and shown in Table 2. The sum of the pozzolanic oxides SiO2, Al2O3 and Fe2O3 was found to be 87.12 %, this shows that the material is a class N pozzolan conforming to ASTM C618-03.
X-ray diffraction (XRD) shows that the major minerals contained in sample CTM as confirmed by the various peaks against corresponding to 2Theta Braggs angle are Chrysotile, Phlogopite, Quartz and Osumilite while the minor minerals found are Anthophylite, Lizardite and Hematite. The diffractogramm is shown in Fig 1.
Sikament NN is a chemical admixture made by Sika Manufacturing Nigeria Limited, located at 10, Western Industrial Avenue Lagos-Ibadan Expressway Isheri, Nigeria. The physical and chemical properties were obtained from the company. It has a pH value of approximately 8, density of 1.20kg/lit, poly-naphthalene condensate base and has no chloride content. Sikament NN complies with ASTM C-494 Type A & F and EN 934:2001. It was administered in the range of 1.0, 1.5, 2.0, 2.5 and 3.0% by mass of cement in line with the manufacturer's prescription.

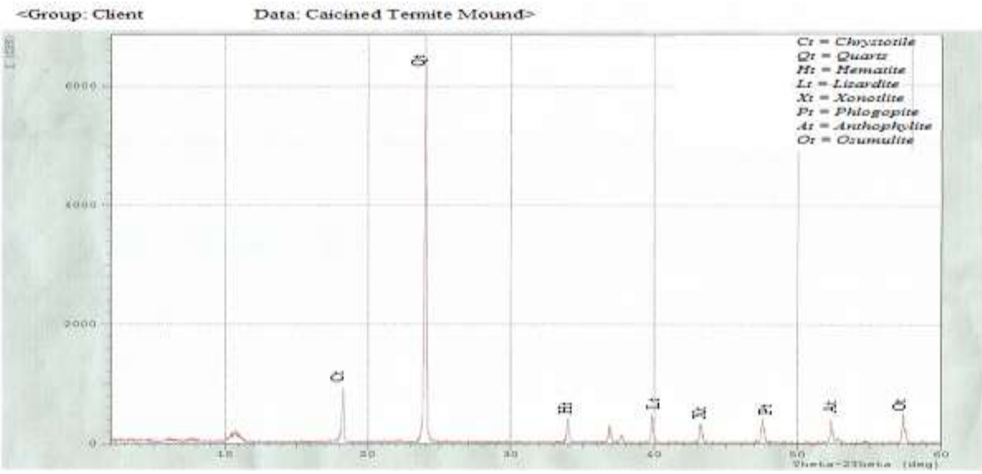

Figure 1: Diffractogramm of Calcined Termite Mound

IV. METHODOLOGY

The mix for the production of concrete was designed for a concrete grade 25 (f_{cu} 25) N/mm^2, using the absolute volume method conforming to ACI 211.1 (2009), having a mix proportion of 1:2:3 and water-cement ratio of 0.5. CTM was used to replace cement by weight in the range 5, 10 and 15 %. For each of the replacement level, Sikament NN was administered at 1.0, 1.5, 2.0, 2.5 and 3.0 % by weight of cement. Results for normal consistency, setting times, slump and compressive strengths were recorded.

V. RESULTS AND DISCUSSION

5.1 Consistency and Setting Times

The results for normal consistency and setting times is shown in Table 3. The result obtained from normal consistency gave 32.5% for the reference mix, 33.5, 34.8 and 36.2 % for 5%, 10 and 15 % replacement respectively and this implies that the higher the quantity of CTM, the higher the amount of water required. This shows that the CTM has affinity for water and this would be as a result of the fineness of the CTM resulting into more surface area, thereby requiring more water to attain normal consistency. As Sikament NN was administered in ranges, the normal consistency reduces which confirms that the admixture is a water reducing agent.

Table 3: Consistency and Setting Times of CTM

Material	Water (%)	Sikament NN (%)	Normal Consistency (%)	Initial Setting Time	Final Setting Time
Cement	100	0	32.5	90	220
95 % Cement and 5 % CTM	100	0	33.5	107	248
	80	1.0	36.0	232	380
	80	1.5	30.0	183	345
	80	2.0	26.2	147	320
	80	2.5	23.3	138	305
	80	3.0	23.0	118	298
90 % Cement and 10 % CTM	100	0	34.8	82	218
	80	1.0	28.0	128	304
	80	1.5	26.5	124	318
	80	2.0	26.0	112	327
	80	2.5	24.5	105	303
	80	3.0	24.0	92	290
85 % Cement and 15 % CTM	100	0	36.2	70	200
	80	1.0	26.0	155	280
	80	1.5	24.4	115	300
	80	2.0	25.5	105	310
	80	2.5	24.0	90	280
	80	3.0	24.5	80	270

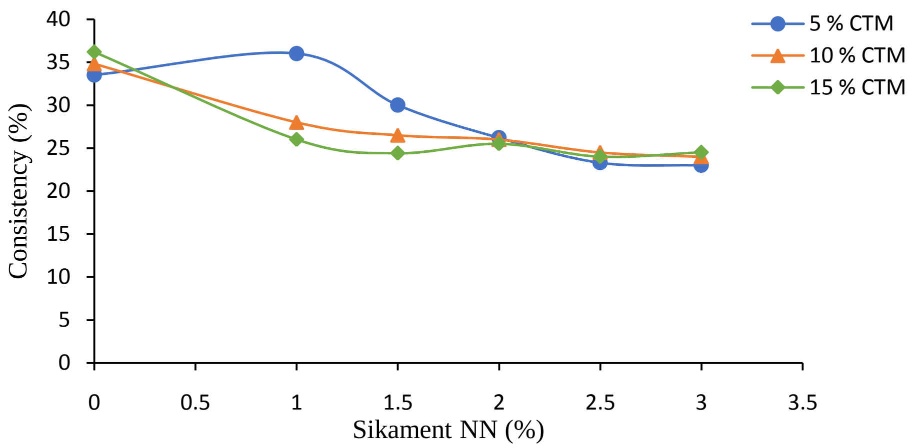

Figure 2: Relationship between Consistency and Sikament NN Replacement

From Figure 2 it was observed that from 2 to 3 % addition of Sikament NN there is no significant difference in the standard consistency for all replacement levels of cement with CTM and a uniform and stable trend is observed. This shows that between 2 to 3 % addition of Sikament NN the consistency is almost the same for all replacements of cement with CTM.

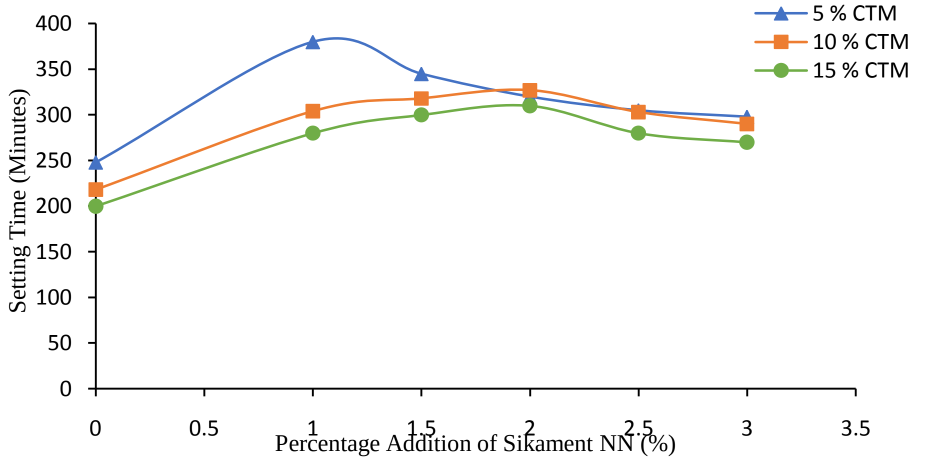

Figure 3: Relationship between Initial Setting Time and Sikament NN Replacement

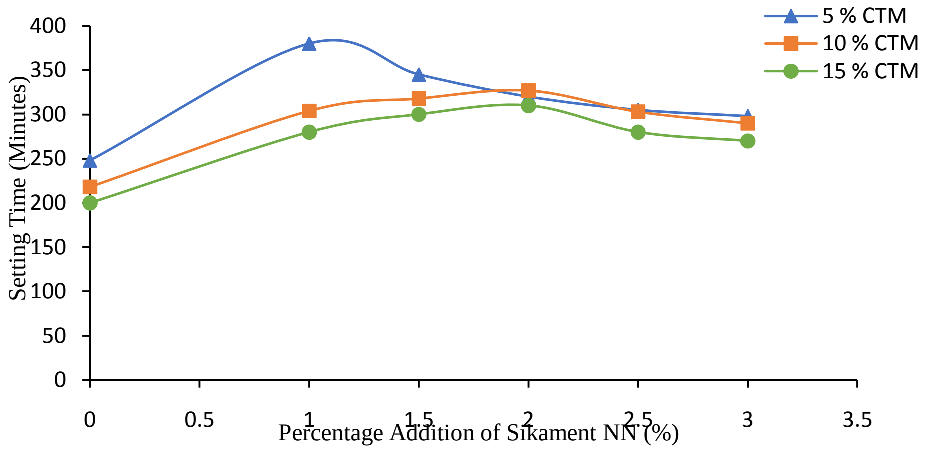

Figure 4: Relationship between Final Setting Time and Sikament NN Replacement

Figures 3 and 4 shows the relationship between initial and final setting times respectively and the percentage addition of Sikament NN. As the percentage replacement of CTM increases, the initial and final setting times reduces. This finding might be as a result of the availability of chrysotile ($Mg_3Si_2O_5(OH)_4$) in the CTM. [14] found that during hydration the heat reactions are intensified in the presence of chrysotile. This might then in turn be responsible for accelerating the setting times upon introduction of CTM making the material suitable for use in cold weather concreting. A similar trend was observed when Sikament NN was added between1 and 2 % but after that a gradual decrease was recorded for all replacement levels.

5.2 Slump (Workability)

The results for slump shown in Table 4 shows that the workability of the concrete mix became less workable upon the introduction of CTM, at 1.0 % addition of Sikament NN a zero slump was recorded for all replacement levels of cement with CTM. An improved workability was recorded when Sikament NN was administered above 1 %. Collapse slump was recorded when Sikament NN was administered above 2 % for 5 % CTM replacement and above 2.5 % for 10 and 15 % of cement replacement with CTM. A slump of 80 mm was recorded for the reference mix.
Figure 5 is the relationship between Sikament NN addition and the slump (workability) and shows that Sikament NN at 1 % no slump was observed but after that rapid increase was recorded reaching its peak at 3 %.

Table 4: Slump Test Results

Sikament NN (%)	5 % CTM (mm)	10 % CTM (mm)	15 % CTM (mm)
0	55	30	15
1.0	0	0	0
1.5	15	5	0
2.0	40	20	8
2.5	100	40	33
3.0	155	120	110

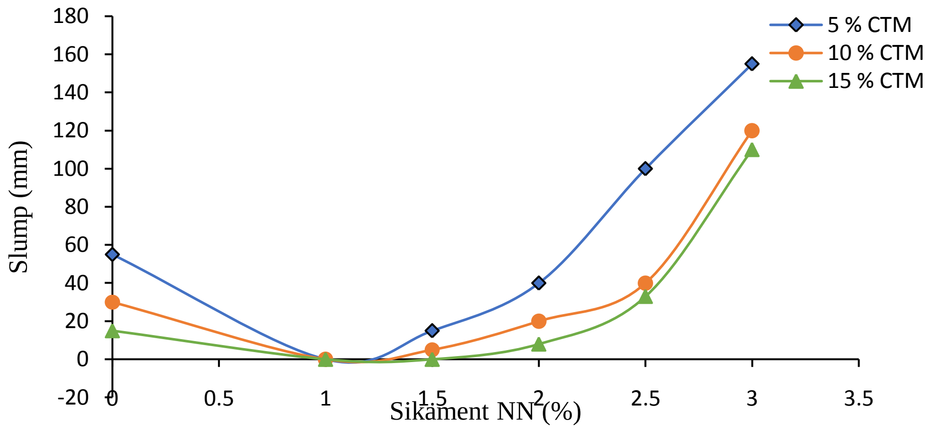

Figure 5: Relationship between Slump and Sikament NN Addition

5.3 Compressive Strength

The compressive strength results obtained shows that CTM is a pozzolana and can replace cement not exceeding 10 % by weight for better results. Compressive strength recorded for CTM at 5 and 10 % replacement have strengths above the reference mix after curing for 90 days. Upon the administration of Sikament NN, compressive strength improved significantly with 5 % CTM replacement having best result at 3.0 % while 10 and 15 % CTM replacements have their best result at 1.0 % addition of Sikament NN. Table 5 shows the compressive strength test results.

Table 5: Compressive Strength Test Results

Material	Sikament NN (%)	Curing Age (Days) 3	7	28	60	90
Control	0	18.60	20.23	33.14	33.70	35.40
95 % Cement and 5 % CTM	0	16.23	18.51	27.29	30.81	38.30
	1.0	18.03	27.23	33.75	36.37	37.54
	1.5	20.19	28.63	35.70	41.96	42.20
	2.0	21.05	28.74	36.44	42.92	44.72
	2.5	19.94	28.14	38.06	40.10	45.93
	3.0	17.00	25.87	35.01	36.98	46.22
90 % Cement and 10 % CTM	0	16.83	18.21	30.19	32.15	40.83
	1.0	19.48	28.99	33.80	39.37	43.63
	1.5	17.69	27.39	38.15	39.46	44.40
	2.0	17.51	25.37	33.30	39.10	43.77
	2.5	16.80	23.78	29.66	38.28	41.93
	3.0	13.39	21.69	28.32	37.30	39.65
85 % Cement and 15 % CTM	0	17.77	18.91	23.58	24.94	33.90
	1.0	19.34	20.01	30.80	38.03	42.08
	1.5	18.40	17.99	32.18	35.70	41.02
	2.0	17.71	17.06	36.43	34.12	40.85
	2.5	16.81	16.68	32.09	33.50	39.29
	3.0	15.52	15.34	30.44	30.12	38.29

Relationship between compressive strength and replacement levels of CTM is shown in Figure 6 while Figures 7 to 11 shows the relationship between compressive strength and Sikament NN percentage addition for 3, 7, 28, 60 and 90 days respectively. The compressive strength of mixes having 5 and 10 % CTM replacing cement shows strength improvement of 7.6 % and 13.3 % respectively above the reference mix after 90 days, while 15 % replacement recorded a compressive strength reduction of 4.4 %. As the Sikament NN is being administered, workability improved significantly at the early stage of administration, but at later stages the slumps collapsed. However, improved compressive strengths were recorded with respect to the reference mix upon the administration of Sikament NN, 23.4, 20.3 and 13.7 % compressive strength improvement was recorded respectively for 5, 10 and 15 % replacement of cement with CTM.

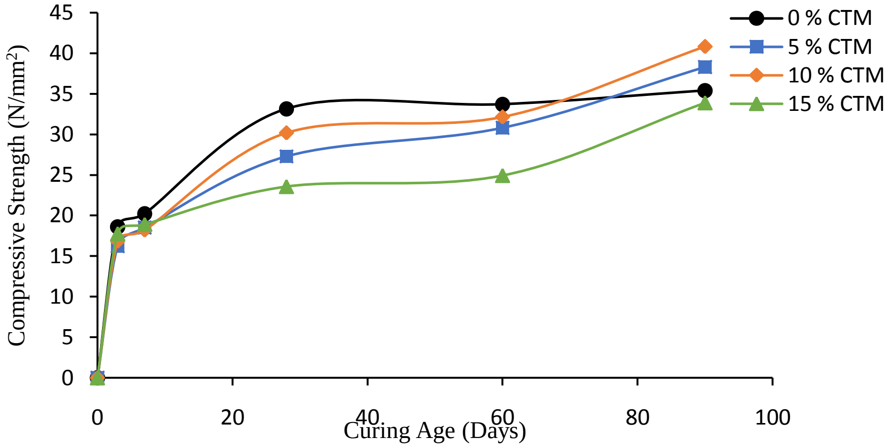

Figure 6: Relationship between Compressive Strength and Curing Age of CTM Concrete

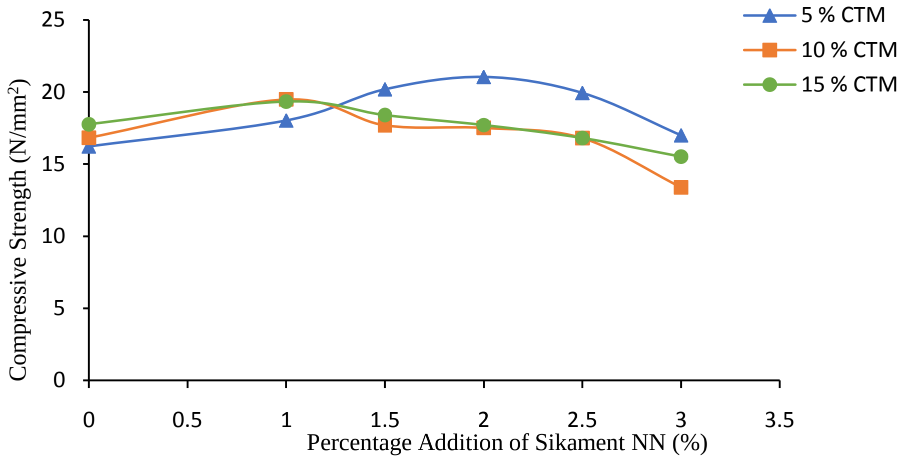

Figure 7: Relationship between 3 days Compressive Strength and Sikament Addition

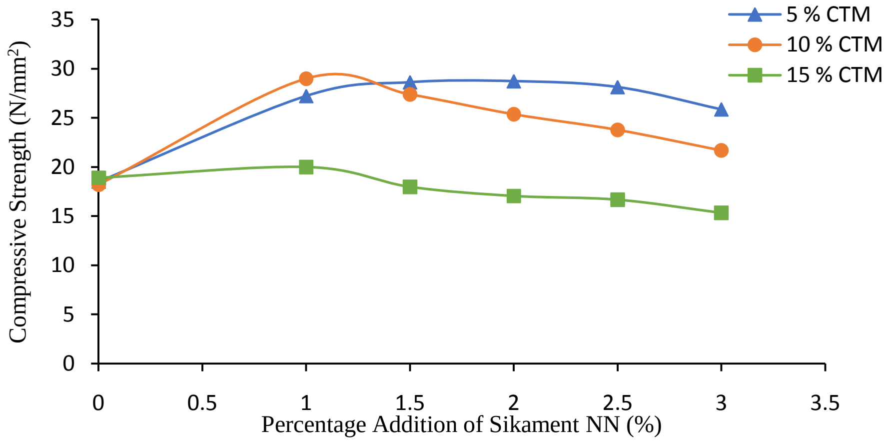

Figure 8: Relationship between 7 days Compressive Strength and Sikament Addition

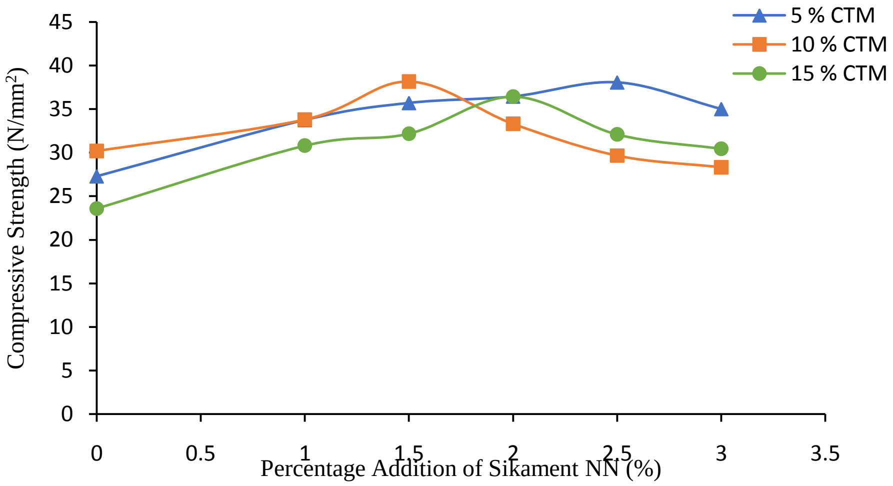

Figure 9: Relationship between 28 days Compressive Strength and Sikament Addition

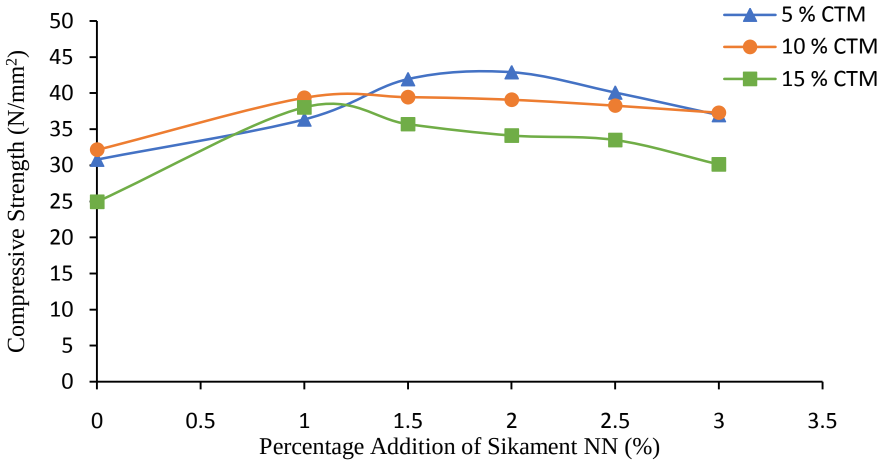

Figure 10: Relationship between 60 days Compressive Strength and Sikament Addition

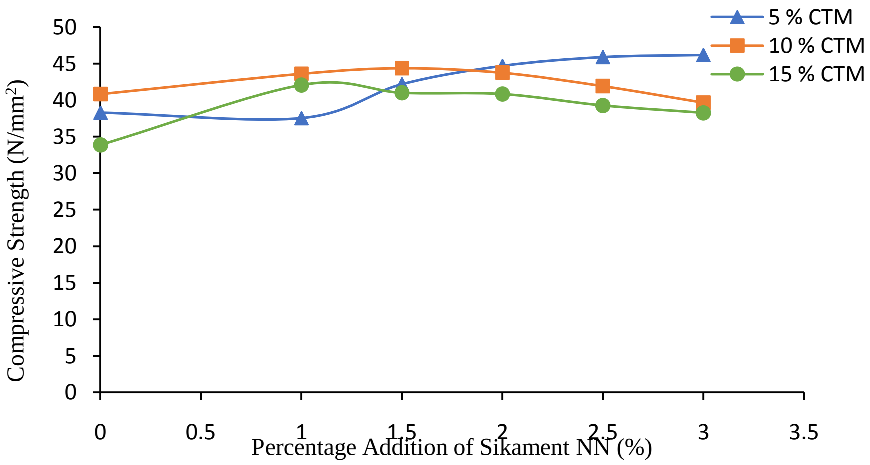

Figure 11: Relationship between 90 days Compressive Strength and Sikament Addition

From the result of XRD, quartz is found to be one of the major minerals. Quartz increases the compressive strength of concrete with increasing surface area, with compressive strength reaching its optimum value at a quartz surface area comparable to that of cement [15]. This finding might be responsible for strengths recorded when CTM was used to replace cement in the mix.

VI. CONCLUSION

From results obtained above, the following conclusions can be drawn:

i. The CTM is proven to be pozzolanic and can be used to replace cement in concrete production but the replacement level should not exceed 10 % replacement by weight of cement.
ii. For best results when using CTM the concrete should be cured for more than 28 days.
iii. The Sikament NN has proven to be an efficient water reducing agent and superplasticizer.
iv. Though best result for compressive strength was achieved at 15 % CTM and 1.0 % Sikament NN, 10 % CTM and 1.0 % Sikament NN is recommended for use because it favours results for both CTM replacement and Sikament NN addition.

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