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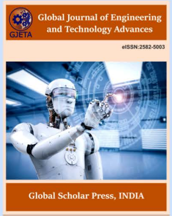

(RESEARCH ARTICLE)

Optimization of Calcined Termite-Mound Material (CTM) Mortar and Concrete using Response Surfaces Methodology

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Abstract

This study is aimed at the optimization of calcined termite mound material incorporated in mortar and concrete using Response Surfaces Methodology (RSM). The calcined termite mound material substituting cement in mortar and concrete varied from 5 to 15% at interval of 5% in mortar and concrete. Sikament NN was added from 1.0 to 3.0 at interval of 1.0. Test conducted on mortar were: consistency and setting times. For concrete, specimens were cast and tested to failure for all the mixes for curing periods of 3, 7, 28, 60 and 90 days. Modelling and optimization were carried out using Design-Expert software version 11.0 with CTM (5%, 10% and 15%) and Sikament NN (1.0%, 2.0% and 3.0%) levels taking as the input variables. The output responses for mortar were consistency, setting times, on concrete compressive strength test after 3, 7, 28, 60 and 90days curing. Comparison was made to the performance of CTM blended mortar and concrete with controls mortar and concrete in terms of consistency, setting times and in concrete compressive strengths. Results from analysis of variance (ANOVA) indicate that both CTM and Sikament are influential variable in the developed models and all the RSM models are statistically significant in all the factor levels. The optimum mix for mortar was obtained by addition of 2.09 % Sikament NN and 5% CTM replacement with 0.871 desirability. In concrete, 2.05 % Sikament NN and 5% CTM replacement with desirability 0.871 was the optimum.

Keywords: Calcined Termite Material; Sikament NN; Consistency; Setting Times; Compressive Strength; Response Surface Methodology; Optimization

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1. Introduction

Presently, construction industries are faced with major challenge of enormous emission of carbon dioxide (CO_2) associated with cement production used in concrete production for infrastructural development. Cement production account for about 7% global CO_2 emission (Maraghechi, et al., 2018). However, it was observed for every ton of ordinary Portland cement produced, nearly 1 ton of CO_2 is emitted (He, et al., 2019). To reduce the amount of CO_2 emission resulting from cement production, researchers are exploring for alternative sustainable eco-friendly cementitious materials that will replace cement in part to form blende cements or completely in concrete. The use of supplementary Cementitious materials (SCMs) replacing conventional materials has a huge potential to reduce CO_2 emissions and precious resource consumption in cement production, especially for developing countries (Maraghechi, et al., 2018).

ASTM C125 defined Pozzolan as a siliceous or alumino-siliceous material that, in finely divided form and in the presence of moisture, chemically reacts at ordinary room temperature with calcium hydroxide, released by the hydration of Portland cement, to form compounds possessing cementitious properties. Presently, supplementary Cementitious materials used in concrete production are mainly by-products from industrial production, such as fly

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ash (FA), silica fume (SF), granulated blast furnace slag (GBFS), etc. the prevalent of utilization of fly ash from coal-based thermal plant for cement replacement in concrete were reported by many researchers (Shabab, 2016). However, when compared with other sources of generating electricity, coal-based thermal plants have high cost per unit of electricity (Ghonaim & Morsy, 2020) contributing enormous amount of CO_2 into the atmosphere (Latawiec, et al., 2018). Hence, the decreasing supply of pozzolanic materials once those plants got decommission permanently may necessitate the need to look for other sources.

Research in this direction, lead to the utilization of both natural and artificial pozzolans in the production of concrete (Jaskulski, et al., 2020). Natural pozzolans are mainly products result from volcanic origin. The second group is clay-based materials such as calcined clay and soil as supplementary cementitious material.

Termites mounds are heaped pile of earth built by termites and are distributed all over the world from 47° Northern latitude to 47° Southern latitude. They are extremely abundant in the tropical rain forest (Claudius & Duna, 2017). Termite mound are readily available in Africa including Nigeria and Ghana (Mahamat & Azeko, 2018). Prior works by (Claudius, et al., 2017and Mahamat & Azeko, 2018) have explored the use of termite's mound soil (TMS) to replace cement in mortar and concrete. They reported without calcination, TMS can replace cement in concrete up to 5% (Mahamat & Azeko, 2018). However, when calcined termite mound material is ground into fine form and used to partially replace cement produces concrete with compressive strength greater than the reference mix (Elinwa, 2006) and up to 10% replacement is possible Claudius & Duna, 2017. Although previous studies reported significant increase in strength, CTM concrete requires more water content to attain a standard consistency, which means the material has affinity for water (Claudius & Duna, 2017). It was concluded Termites mound material is proven to be pozzolanic and can be used to replace cement in concrete.

This paper aim to find the optimum of CTM and Sikament NN (as superplasticizer and water reducing agent) incorporated in concrete replacing cement by weight at 5%, 10% and 15%, and addition of Sikament NN at 1%, 2% and 3% by weight of cement as variables using response surfaces methodology (RSM) to obtained response surface models for consistency, settings, slump and compressive strengths for 7, 28 and 90days. The design of experiment chosen to conduct the study is Face-Centered Central Composite Design (FCCCD) method of the experimental design.

According to Montgomery (2001), response surface methodology (RSM) is a collection of mathematical and statistical techniques used for modeling and analyzing of problems in which a response of interest is influenced by several variables and the objective is to optimize this response. Following the traditional experimental design method to evaluate the influence of different parameters at various levels on properties concrete results to large number of experimental runs, this is expensive and time consuming. Researchers have utilized RSM to obtain an appropriate mathematical model, capable of minimizing the number of experiments required and at the same time, producing a highly effective tool for data analysis and interpretation, allowing efficiency and economy in the experimental process and scientific objectivity in the conclusions (Pinheiro, et al., 2020).

Optimization of bentonite modified cement mortar parameter at elevated temperatures was performed by Vijay & Reddy (2021) using RSM. Individual, combined and quadratic effect of the variables on the responses compressive and strength index were analyzed. The result shows the models can predict the compressive and strength index. The Optimum solution was at 20% calcined bentonite and temperatures 200°C with a desirability of 0.9.

Multi-objective Optimization of calcined bentonite concrete was carried out by Sahith-Reddy et al., (2021) to find the relation between independent variables and the responses using CCD of the RSM. The independent variables are calcined bentonite varied from 0%, 15% and 30% replacing cement in concrete and w/c ratio of 0.6, 0.65, and 0.7. The responses are: slump value, compaction factor, 28days compressive strength, split tensile strength, flexural strength and charge passed through concrete at 28days. The models created from RSM are statistically significant in all the factors range considered. The optimum solution was obtained with 3.92% bentonite substitution and 0.62 W/C ratio with 0.88 desirability.

2. Materials and method

In this experimental investigation, calcined termite mound material was used in the concrete as a partial substitute for cement in concrete by weight percentages such as 5%, 15% and 30%. The calcination of termite mound material was done with a kerosene fueled kiln at approximate working temperature of 800°C for a period of one hour at the Industrial Design Department of Abubakar Tafawa Balewa University, Bauchi. The Physical and chemical Properties of calcined termite mound material results conforms to EN 1097-6 and BS EN ISO 17892 is shown in Table 1. The Oxide composition was determined using X-Ray Fluorescence (XRF) and shown in Table 1. The sum of basic oxides SiO_2, $Al2O_3$ and $Fe2O_3$ was found to be 87.12 %, indicating the termite mound is class N pozzolan conforming to the ASTM C618-03. The result of X-ray diffraction (XRD) termite mound material shows the major minerals contained in CTM sample as indicated by the various peaks against corresponding to 2Theta Braggs angle were Chrysotile, Phlogopite, Quartz and Osumilite and the minor minerals found were Anthophylite, Lizardite and Hematite as shown in figure 1.

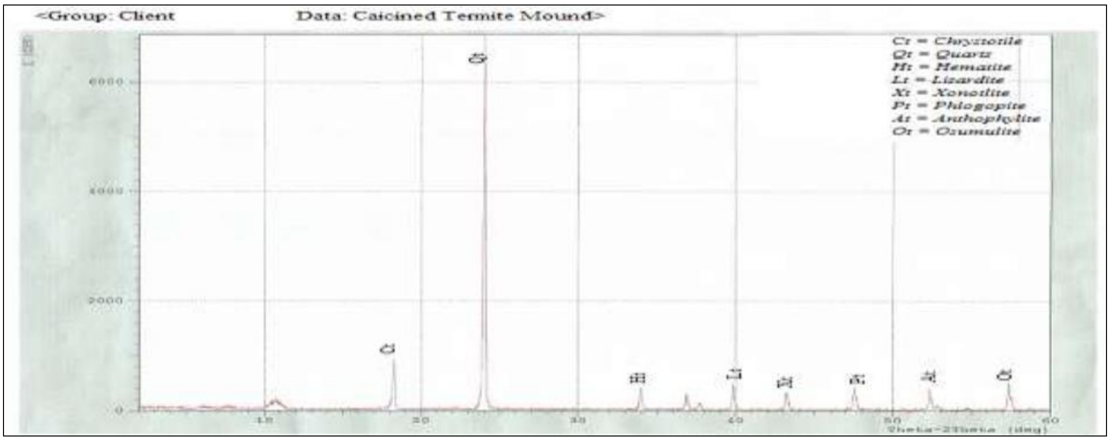

Figure 1 Diffractogramm of Calcined Termite Mound

Table 1 Physical and chemical Properties of CTM

Physical Properties	
Parameter (Unit)	**Value**
Moisture Content (%)	16.35
Specific Gravity	2.53
Liquid Limit (%)	28.00
Plastic Limit (%)	0.0
Plasticity Index (%)	28.00
Chemical Properties	
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	30.07
TiO_2	1.05
LOI	3.93

The cement used in the study was Dangote brand of Ordinary Portland Cement OPC-42.5R conforming to BS EN 197 Part 1&2: (2000) specifications with specific gravity of 3.15. Fine aggregate was used, which confirming to BS 812 (1995). The value of specific gravity and bulk density obtained were 2.63 and 1525kg/m^3 respectively. Crushed normal weight aggregate from igneous rock source was used for the study, with the size range 5 to 10 and 20mm, of bulk density 1485kg/m^3, specific gravity 2.63, water absorption 0.15, aggregate impact 14.91% values (AIV) and crushing values (ACV) of 15.52%. The water used for the concrete mix was from a tap suitable for drinking, no test was conducted on the water.

Chemical admixture used was Sikament NN Manufactured by Sika Nigeria Limited conforming to ASTM C-494 Type A & F and EN 934:2001. It has a pH value of 8, density of 1.20kg/lit, poly-naphthalene condensate base and has no chloride content.

The normal concrete mix design of grade M25 concrete with water cement ratio of 0.45 designed on the basis of the procedures of American concrete institute (ACI 211, 2003) absolute volume method for normal concrete was adopted in the study. CTM was used to replace cement by weight in the range 5, 10 and 15 %. At 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 as per the recommendation of the manufacturer. Table 1 shows the Concrete mix proportions. For mortar, the results of normal consistency initial setting time and final setting time were recorded. For concrete, slump values and compressive strengths after curing for the period of 3, 7, 28 and 90days were recorded.

Table 2 Mortar and Concrete mix proportions

S/NO	Mortar				Concrete				
	Water	**Cement**	**Sikament NN**		**Cement**	**Fine Aggregate**	**Coarse Aggregate**	**Water**	**Sikament NN**
0% CTM (Control)									
1			0.0		430.23	842.77	1570.30	185	0.0
5% CTM									
2			0.0			842.77	1570.30	185	0.0
3			1.0			842.77	1570.30	185	1.0
4			2.0			842.77	1570.30	185	2.0
5			3.0			842.77	1570.30	185	3.0
10% CTM									
6			0.0			842.77	1570.30	185	0.0
7			1.0			842.77	1570.30	185	1.0
8			2.0			842.77	1570.30	185	2.0
9			3.0			842.77	1570.30	185	3.0
15% CTM									
10			0.0			842.77	1570.30	185	0.0
11			1.0			842.77	1570.30	185	1.0
12			2.0			842.77	1570.30	185	2.0
13			3.0			842.77	1570.30	185	3.0

3. Experimental design

The properties of mortar and concrete incorporating calcined termite mound material were analyzed and relationships developed based on face-centered central composite design (FCCD) of the experiment (DOE) of the response surface methodology (RSM). In FCCD, axial points in the experimental domain are at the center of each face of the factorial space. Second order quadratic response surfaces model was used as predicting equation to analyze the responses using Design-Expert version 11.0 software. Equation (1) shows the predicting equation.

The design matrix at 3 levels and two factors combinations with percentage of CTM (5, 10, and 15) coded as A and Sikament NN (1.0, 2.0, and 3.0) is coded as B as shown in Table 3. Normal consistency, initial setting time, final setting time, slump values and compressive strengths at curing age of 3, 7, 28 and 90days are the response variables.

$$Y = \beta_0 + \beta_1 A + \beta_2 B + \beta_{12} AB + \beta_{11} A^2 + \beta_{22} B^2 \quad \text{………………..Eq.1}$$

Where:
Y is predicted response; β_0 is intercept;
β_1, β_2 are linear effect coefficients;
β_{11}, β_{22} are quadratic effect coefficients
β_{12} is interaction effect coefficient.

Table 3 Concrete Mix Proportion In terms of Coded and Actual Factors

S/NO	Coded Factors		Actual Factors	
	A	B	CTM (%)	Sikament NN (%)
1	-1	0	5	2
2	0	0	10	2
3	0	-1	10	1
4	+1	+1	15	3
5	+1	0	15	2
6	0	0	10	2
7	-1	-1	5	1
8	+1	-1	15	1
9	0	0	10	2
10	+1	+1	10	3
11	-1	+1	5	3
12	0	0	10	2
13	0	0	10	2

4. Results and discussion

The result of consistency, initial and final setting times presented in table 4. The result shows consistency, initial and final setting times decreases with the increase in CTM at all levels of Sikament NN addition. Implying 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 (Claudius & Duna, 2017). The reduction in setting times due to the increase in CTM addition, as a result of the availability of chrysotile ($Mg_3Si_2O_5(OH)_4$) in the CTM (Claudius & Duna, 2017; Kavas et al., 2004).

The results of slump values, 3, 7, 28, 60 and 90 days' compressive strengths are presented in table 4. An experimental result shows the slumps values decreases with increase in parentage the of CTM replacement. Administering of above 1.0% of Sikament NN show improve in walkability of all the mix, at higher doses of Sikament NN collapse slump was recorded. Compressive strength test result shows an increase in strength above the control concrete with the addition of CTM from 5% to 10% after curing for 90days. This may be attributed to the pozzolanic activity and improvement in the C-S-H formation upon appropriate substitution of CTM in concrete (Sahith-Reddy et al., 2021). Similarly, XRD results indicate quartz as the major minerals in CTM. 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 (Claudius & Duna, 2017; Danielle et al., 1996). The effect of CMT replacement and Sikament NN addition in mortar and concrete is study using RSM.

The results of analysis of variance (ANOVA) of the responses, consistency, initial and final setting times, slump values and compressive strengths of 3, 7, 28, 60 and 90days curing periods are shown in tables 7, 8 9, 10, 11, 12, 13, 14, 15 and 16 respectively. The Fisher test (F-value test) for all the quadratic models indicated the models are statistically significant at 5% level of significant. P-value was used to check the individual model terms significant at 5% level of significant. The significant model terms are shown in the ANOVA tables. The coefficient of determination (R^2) and adjusted coefficient of determination (adjR^2) are close to each other and close to unity (1) indicating the models are good as in table 6. Equations 2, 3 4, 5, 6, 7, 8, 9 and 10 are the final response surfaces models.

Table 4 Consistency, Initial Setting and Final Setting Time of CTM

S/No.	Coded Factors		Normal Consistency (%)	Setting Times	
	A	B		Initial	Final
1	-1	0	26.20	147	320
2	0	0	20.00	112	327
3	0	-1	28.00	128	302
4	+1	+1	24.50	80	270
5	+1	0	25.50	105	310
6	0	0	20.00	112	327
7	-1	-1	36.00	232	380
8	+1	-1	26.00	155	280
9	0	0	20.00	112	327
10	+1	+1	24.00	92	290
11	-1	+1	23.00	118	298
12	0	0	20.00	112	327
13	0	0	20.00	112	327

Table 5 Slump value and Concrete strength values for 3, 7, 28 and 90days curing periods

S/NO	Coded Factors		Slump (mm)	Curing Age (Days)				
	A	B		3	7	28	60	90
1	-1	0	40	21.05	28.74	36.44	42.92	44.72
2	0	0	20	17.51	25.37	33.30	39.10	43.77
3	0	-1	30	19.48	28.99	33.80	39.37	43.63
4	+1	+1	110	15.52	15.34	30.44	30.12	38.29
5	+1	0	8	17.71	17.06	36.43	34.12	40.85
6	0	0	20	17.51	25.37	33.30	39.10	43.77
7	-1	-1	0	18.03	27.23	33.75	36.37	37.54
8	+1	-1	0	19.34	20.01	30.80	38.03	42.08
9	0	0	20	17.51	25.37	33.30	39.10	43.77

10	+1	+1	110	13.39	21.69	28.32	37.30	39.65
11	-1	+1	155	17.00	25.87	35.01	36.98	46.22
12	0	0	20	17.51	25.37	33.30	39.10	43.77
13	0	0	20	17.51	25.37	33.30	39.10	43.77

The effect of each variable on the properties is plotted as 3-dimensional response surfaces as shown in figure 2, 3 and 4. From the figures, the effect of each variable on the property can be seen as consistency, initial and final setting times decreases with the increase in CTM at all levels of Sikament NN addition. In concrete, from the response surfaces plots as illustrated in the figures 5, 6, 7, 8, 9, and 10, Slump values decreases with an increase in CMT and walkability improvement with addition of percentage of Sikament NN. However, compressive strength increases with increases in CTM and Sikament NN percentages and curing periods.

Table 6 Analysis of variance for consistency (%) response

Source	**Sum of squares**	**DF**	**Mean square**	**F-value**	**P-value**
Model	108.13	5	21.63	16.23	0.0010
A-CTM (%)	14.11	1	14.11	10.59	0.0140
B-Sikament NN (%)	57.04	1	57.04	42.82	0.0003
AB	33.06	1	33.06	24.82	0.0016
A^2	0.95	1	0.95	0.71	0.4265
B^2	1.50	1	1.50	1.12	0.3243
Residual	9.33	7	1.33		
Lack of fit	9.33	3	3.11		
Pure error	0.000	4	0.000		
Total	117.46	12			

Table 7 Analysis of variance for initial setting time (%) response

Source	**Sum of squares**	**DF**	**Mean square**	**F-value**	**P-value**
Model	14075.93	5	2815.19	14.43	0.0014
A-CTM (%)	1350.00	1	1350.00	6.92	0.0339
B-Sikament NN (%)	4160.67	1	4160.67	21.33	0.0024
AB	2809.00	1	2809.00	14.40	0.0068
A^2	2976.37	1	2976.37	15.26	0.0059
B^2	782.08	1	782.08	4.01	0.0853
Residual	1365.30	7	195.04		
Lack of fit	1365.30	3	455.10		
Pure error	0.000	4	0.000		
Total	15441.23	12			

Table 8 Analysis of variance for final initial setting time (%) response

Source	**Sum of squares**	**DF**	**Mean square**	**F-value**	**P-value**
Model	4764.19	5	952.84	7.08	0.0116
A-CTM (%)	1504.17	1	1504.17	11.18	0.0124
B-Sikament NN (%)	192.67	1	192.67	1.43	0.2705
AB	2500.00	1	2500.00	18.58	0.0035
A^2	105.81	1	105.81	0.79	0.4047
B^2	565.60	1	565.60	4.20	0.0795
Residual	942.11	7	134.59		
Lack of fit	942.11	3	314.04		
Pure error	0.000	4	0.000		
Total	5706.31	12			

Table 9 Analysis of variance for Slump value response

Source	**Sum of squares**	**DF**	**Mean square**	**F-value**	**P-value**
Model	32250.34	5	6450.07	527.10	< 0.0001
A-CTM (%)	988.17	1	988.17	80.75	< 0.0001
B-Sikament NN (%)	24704.17	1	24704.17	2018.83	< 0.0001
AB	506.25	1	506.25	41.37	0.0004
A^2	71.45	1	71.45	5.84	0.0463
B^2	4662.31	1	4662.31	381.00	< 0.0001
Residual	85.66	7	12.24		
Lack of fit	85.66	3	28.55		
Pure error	0.000	4	0.000		
Total	32336.00	12			

Table 10 Analysis of variance for 3-days compressive strength (MPa) response

Source	**Sum of squares**	**DF**	**Mean square**	**F-value**	**P-value**
Model	32.42	5	6.48	9.87	0.0045
A-CTM (%)	7.06	1	7.06	10.75	0.0135
B-Sikament NN (%)	13.32	1	13.32	20.27	0.0028
AB	0.011	1	0.011	0.017	0.9006
A^2	6.97	1	6.97	10.61	0.0139
B^2	9.52	1	9.52	14.48	0.0067
Residual	4.60	7	0.66		
Lack of fit	4.60	3	1.53		
Pure error	0.000	4	0.000		
Total	37.02	12			

Table 11 Analysis of variance for 7-days compressive strength (MPa) response

Source	**Sum of squares**	**DF**	**Mean square**	**F-value**	**P-value**
Model	205.95	5	41.19	31.55	0.0001
A-CTM (%)	144.35	1	144.35	110.57	< 0.0001
B-Sikament NN (%)	29.61	1	29.61	22.68	0.0021
AB	2.74	1	2.74	2.10	0.1908
A^2	22.21	1	22.21	17.01	0.0044
B^2	0.43	1	0.43	0.33	0.5830
Residual	9.14	7	1.31		
Lack of fit	9.14	3	3.05		
Pure error	0.000	4	0.000		
Total	215.09	12			

Table 12 Analysis of variance for 28-days compressive strength (MPa) response

Source	**Sum of squares**	**DF**	**Mean square**	**F-value**	**P-value**
Model	56.01	5	11.20	9.24	0.0055
A-CTM (%)	32.71	1	32.71	26.98	0.0013
B-Sikament NN (%)	0.023	1	0.023	0.019	0.8948
AB	0.051	1	0.051	0.042	0.8439
A^2	5.67	1	5.67	4.68	0.0673
B^2	22.86	1	22.86	18.85	0.0034
Residual	8.49	7	1.21		
Lack of fit	8.49	3	2.83		
Pure error	0.000	4	0.000		
Total	64.50	12			

Table 13 Analysis of variance for 60-days compressive strength (MPa) response

Source	**Sum of squares**	**DF**	**Mean square**	**F-value**	**P-value**
Model	95.09	5	19.02	7.58	0.0096
A-CTM (%)	32.67	1	32.67	13.03	0.0086
B-Sikament NN (%)	14.63	1	14.63	5.84	0.0464
AB	18.15	1	18.15	7.24	0.0311
A^2	8.26	1	8.26	3.29	0.1125
B^2	10.12	1	10.12	4.04	0.0845
Residual	17.55	7	2.51		
Lack of fit	17.55	3	5.85		
Pure error	0.000	4	0.000		
Total	112.64	12			

Table 14 Analysis of variance for 90-days compressive strength (MPa) response

Source	Sum of squares	DF	Mean square	F-value	P-value
Model	53.86	5	10.77	7.23	0.0109
A-CTM (%)	14.92	1	14.92	10.01	0.0158
B-Sikament NN (%)	0.28	1	0.28	0.19	0.6791
AB	26.37	1	26.37	17.70	0.0040
A^2	0.80	1	0.80	0.53	0.4883
B^2	7.82	1	7.82	5.25	0.0558
Residual	10.43	7	1.49		
Lack of fit	10.43	3	3.48		
Pure error	0.000	4	0.000		
Total	64.29	12			

Table 15 Model statistics for all response variables

Responses	PredR^2	AdjR^2	F-value	Prob> F	Model comment
Consistency (%)	0.9206	0.8636	16.23	0.0001	Significant
Initial setting time (%)	0.9116	0.8484	14.43	0.0014	Significant
Final stetting time (%)	0.8349	0.7770	7.08	0.0116	Significant
Slump (mm)	0.9974	0.9955	527.10	0.0001	Significant
3-days comp. strength	0.8770	0.7870	9.87	0.0001	Significant
7-days comp. strength	0.9575	0.9272	31.55	0.0001	Significant
28-days comp. strength	0.8684	0.7744	9.24	0.0055	Significant
60-days comp. strength	0.8442	0.7329	7.58	0.0096	Significant
90-days comp. strength	0.8378	0.7219	7.23	0.0109	Significant

Consistancy (%) = +25.79-1.53*A -3.08*B +2.88*A*B +0.59*A^2 +0.74*B^2………Eq.2

Initial setting time (%)=+106.62 -15.00*A -26.33*B +26.50*A*B +32.83*A^2 +16.83*B^2……… Eq.3

Final setting time (%) =+322.5 -15.83*A -5.67*B +25.00*A*B +6.19*A^2 -14.31*B^2 ………Eq.4

Slump (%)= +19.69 -12.83*A +64.17*B -11.25* A*B +5.09*A^2 +41.09*B^2 ………Eq.5

3-Days Comp. (MPa) =+17.59 -1.09*A -1.49*B +0.053*A*B +1.59* A^2 -1.86*B^2………Eq.6

7-Days Comp. (MPa) = +25.47 -4.91* A -2.22* B -0.83*A*B -2.84* A^2 -0.40* B^2 ………Eq.7

28-Days Comp. (MPa)=+33.12 -2.34*A +0.062* B -0.11*A* B +1.43* A^2 -2.88*B^2………Eq.8

60-Days Comp. (MPa)=+39.43 -2.33*A -1.56* B -2.13*A*B -1.73* A^2 -1.9* B^2……… Eq.9

90-Days Comp. (MPa) =+43.64 -1.58*A-0.2*B-2.57*A*B -0.54* A^2 -1.68* B^2……… Eq.10

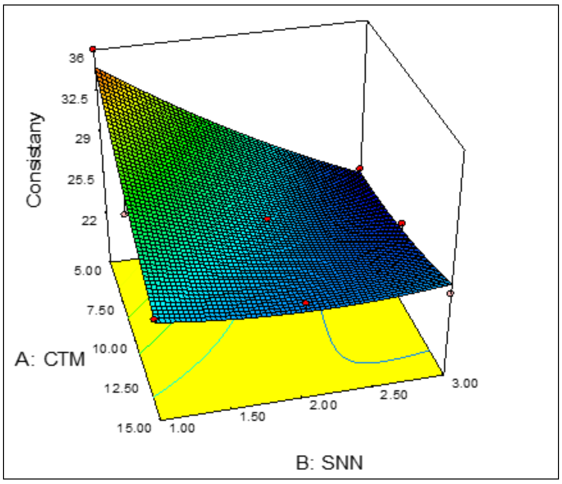

Figure 2 Response Surface and Plot of consistency

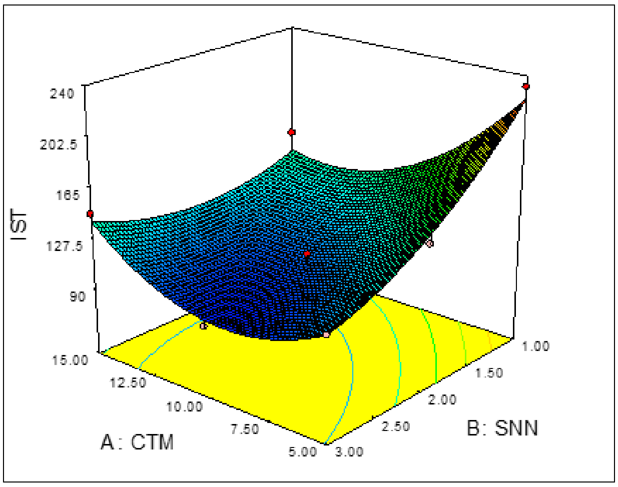

Figure 3 Response Surface Plot of Initial setting time

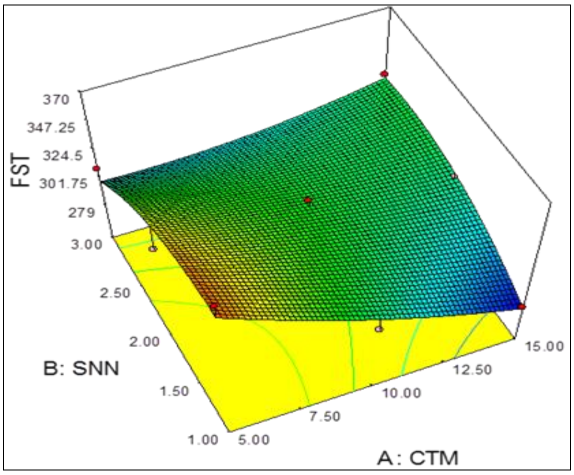

Figure 4 Response Surface Plot of Final setting time

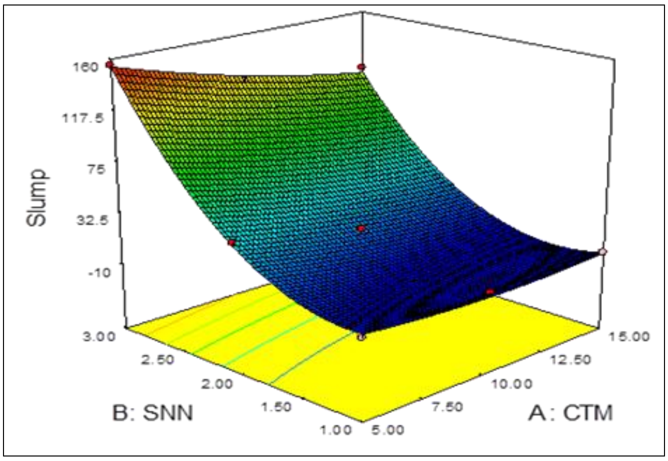

Figure 5 Response Surface and Plot of slump values

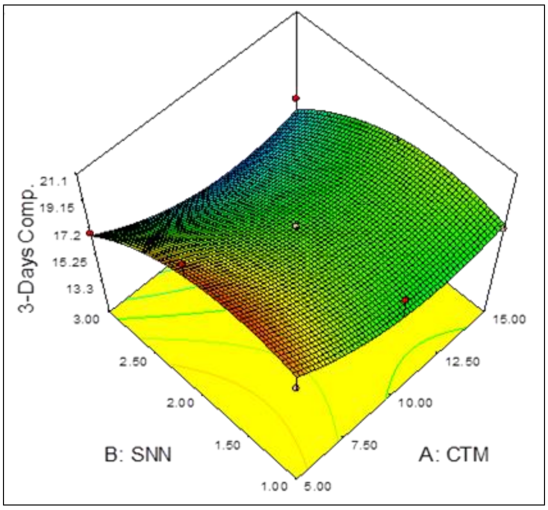

Figure 6 Response Surface and Plot of 3-days compressive strengths

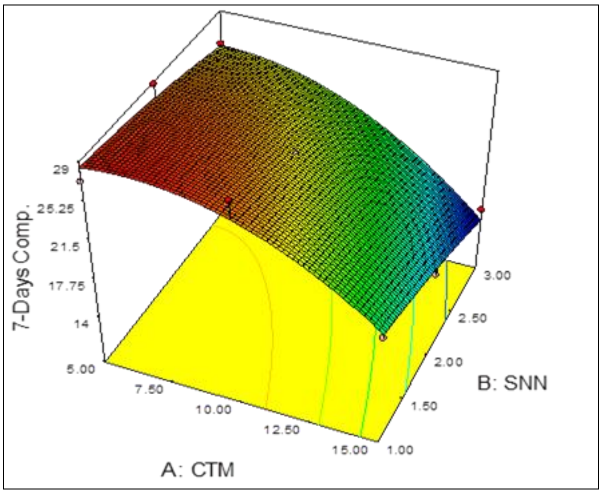

Figure 7 Response Surface and Plot of 7-days compressive strengths

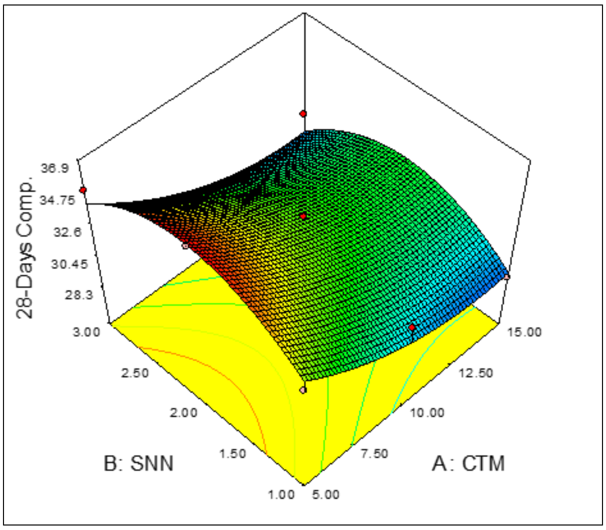

Figure 8 Response Surface and Plot of 28-days compressive strength

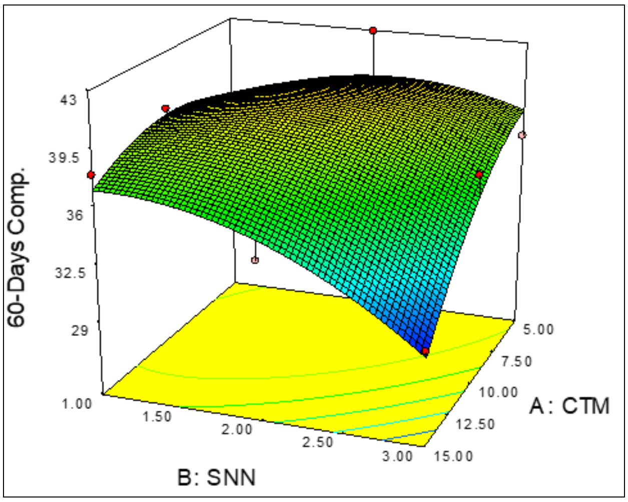

Figure 9 Response Surface and Plot of 60-days compressive strengths

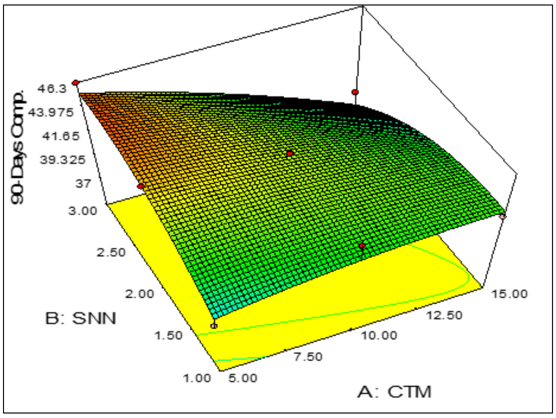

Figure 10 Response surface and plot of 90 days compressive strength

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5. Optimization of mortar and CTMC

To optimist cement mortar and concrete incorporating CTM, the influencing factors have to be at optimum to obtain the desire properties. The optimization of mortar and CTMC mix was performed using numerical optimization using desirability function technics. The optimization of the mortar and CTMC were based on the goals and limits of Table 6. The best setting obtained for mortar is: CTM 14.93 (%) and Sikament NN 2.126 (%) and CTMC is CTM 14.93 (%) and Sikament NN 2.126 (%) with desirability of 1 and 0.871 respectively. indicating the goal of the optimization is fully achieved and good for CTMC respectively.

Table 16 Responses goal and limits of mortar and CTMC for the optimization

S/No.	Name of response	Goals	Lower limit	Upper limit
1	Consistency (%)	In range	23	36
2	Initial setting time (%)	In range	92	232
3	Final stetting time (%)	In range	280	370
4	Slump (medium) (mm)	In range	30	80
5	3-days comp. strength (MPa)	maximise	13.39	21.05

6	7-days comp. strength (MPa)	maximise	15.34	28.90
8	28-days comp. strength (MPa)	maximise	28.32	36.74
9	60-days comp. strength (MPa)	maximise	30.12	42.92
10	90-days comp. strength (MPa)	maximise	38.29	46.22

6. Conclusion

The following conclusions were made based on the experimental results:

- It was observed that the consistency and setting times have shown a decrease upon increasing the percentage of CMT and Sikament NN in Mortar.
- The effect of incorporating CTM in concrete decreases walkability (slump), addition of above 1.0% to Sikament NN improve the walkability.
- Compressive strength improved by the incorporation of 5% and 10% calcined Termite material in Mortar and concrete up to 90 days' age and Sikament. Indicating CMT has proving to be pozzolanic can be to substituted cement in concrete.
- The RSM models developed are significant for all the variables considered. The optimum mix for mortar was obtained by addition of 2.09 % Sikament NN and 5% CTM replacement with 0.871 desirability. In concrete, 2.05 % Sikament NN and 5% CTM replacement with desirability 0.871 was the optimum.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest in the findings of the research reported in this publication.

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