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Durability Performance of Processed Coconut Shell Ash (Local Stabilizer) and Model Prediction of CBR and UCS Values of Ntak Clayey Soils in Akwa Ibom State, Nigeria.

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ABSTRACT
It is very essential to improve on the study of stabilization, as we investigation the potential of Processed Coconut Shell Ash (PCSA) as a Local stabilizer in stabilizing clay soil. The ever-increasing cost of construction materials in Nigeria and other developing countries has created the need for improved research into locally and readily available materials and also on how to convert these local materials such as Coconut Shell Ash for use in construction and soil improvement. To achieve this; soil samples were collected from Ntak – Uyo, Akwa Ibom State classified as an A-2-5 soil on AASHTO and CL on UNIFIED SYSTEM of classification, were sieved and passed through sieve No. 36. It was then stabilized with (2-7)% Processed Coconut Shell Ash (PCSA) by weight of the dry soil. The investigation includes evaluation of the engineering and geotechnical properties of the soil.
The results obtained shows that the increase in PCSA content at 7% increase the Optimum Moisture Content (OMC) by 18.42%, Maximum Dry Density (MDD) by 1.78gm/cm^3, Unconfined Compressive Strength (UCS) by 446.25kN/m^2, California Bearing Ratio (CBR) by 41% for unsoak and 33% for soak while there was a significant reduction in the value of Liquid Limit (LL) by 30% and Plasticity Index (PI) by 20%. A predictive models were developed and these models showed a good correlation with experimental results in the control tests as they possess a reasonable significant difference and a strong relationship between the measured and predicted values.
The study concluded that PCSA can be used to improve the properties of soil for construction purposes and 7% PCSA content was observed to yield maximum improvement for OMC, MDD, CBR and UCS values.

Key words
Processed Coconut Shell Ash (PCSA) Mixture Design Simplex Lattice, Compaction, Consistency, Stabilization, Scheffe's Models.

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I. INTRODUCTION

Road is the key infrastructure of a country. It contributes to the economic, industrial and cultural development of a country. A country's economic status depends upon how well served the country is by its roads. The importance of road is comparable to the veins in the human just as veins in the human body maintain health by circulation of blood to different parts of the body.

Similarly, means of transportation keep the health of a nation in good condition by keeping the goods and people moving from one place to another. Thus, road is vital for the all round development of a nation since every goods and services, need transport facilities both at the production stage as well as distribution stage. In the production stage, road is needed for carrying raw materials such as seeds, manure in the case of food production, sugarcane, cotton, coal, steel etc, in the case of cloth and sugar industry. In the distribution stage transportation is required to transport finished products from farm and factories to the distribution centers. Thus for the economic, cultural and social development of a country, an effective and adequate system of transportation is essential in order words there must be well constructed roads linking the cities because a country's economic status depends so much on how well served the country is by its roads. Hence the rate at which a country's economic grows is very closely linked to the rate at which the transport sector grows.

Coconut shell is the hardest part of **coconut** which located in side of **coconut husk** by protecting **coconut** meat. The burning of coconut shells is not only a waste of natural resources, it also

contributes significantly to CO_2 and methane emissions. The chemical composition of **coconut husks** consists of cellulose, lignin, pyroligneous acid, gas, charcoal, tar, tannin, and potassium. The predominant use of **coconut husks** is in direct combustion in order to make charcoal, otherwise **husks** are simply thrown away. Agricultural waste material, in this case, **coconut shells**, which is an environmental pollutant, are collected and burnt in the open air (uncontrolled combustion) for three hours to produce **coconut shell ash** (CSA), which in turn can be used as pozzolana in soil stabilization and in partial replacement of cement in concrete production.

II. MATERIALS AND METHOD

2.1 Sample Collection, Preparation and Identification

The coconut shells was obtained from different locations within Akwa Ibom State, Nigeria. It was dried, incinerated to a certain temperature in a furnace, allowed to cool then pulverized and the shells sieved through sieve no 36, after which it was processed by adding 1500g of gypsum for every 19300g of additive for experimental study and the specific gravity of the coconut shells and the soil sample was recorded. The soil sample was collected in bags by method of disturbed sampling at reasonable depth in Uyo, Akwa Ibom State. Preliminary tests for identification of the natural soil, stabilizer and the geotechnical properties of the soil treated with stabilizer was carried out in accordance with BS 1377: Part 2: 1990: 4.3/5.3, BS 1377: Part 2: 1990: 8.3 and BS 1377: Part 2: 1990: 9.3 and BS 1377: Part 4: 1990: 3.3/3.5 and BS 1377: Part 4: 1990: 3.4/3.6. The determination of chemical properties for the stabilizer and the soil sample were done in accordance with American Society for Testing and Materials (ASTM) 1999 and American Public Health Association (APHA) 20^{th} Edition 1998. The standard proctor energy level was used for compaction test, which was also used in determining the moisture content for california bearing ratio and unconfined compressive strength specimens. The stabilizer were thoroughly mixed with pulverize soil and then with distill water. The results of the combined percentages of the oxides obtained from the selected materials satisfied certain minimum requirement value as specified at the end of the study for local stabilizers and this standard was compared to the recommended ASTM requirement for English stabilizers, example cement. The loss on ignition showed the extent of carbonation in sample mixtures during test and the maximum value was obtained and compared with the maximum value required for pozzolan.

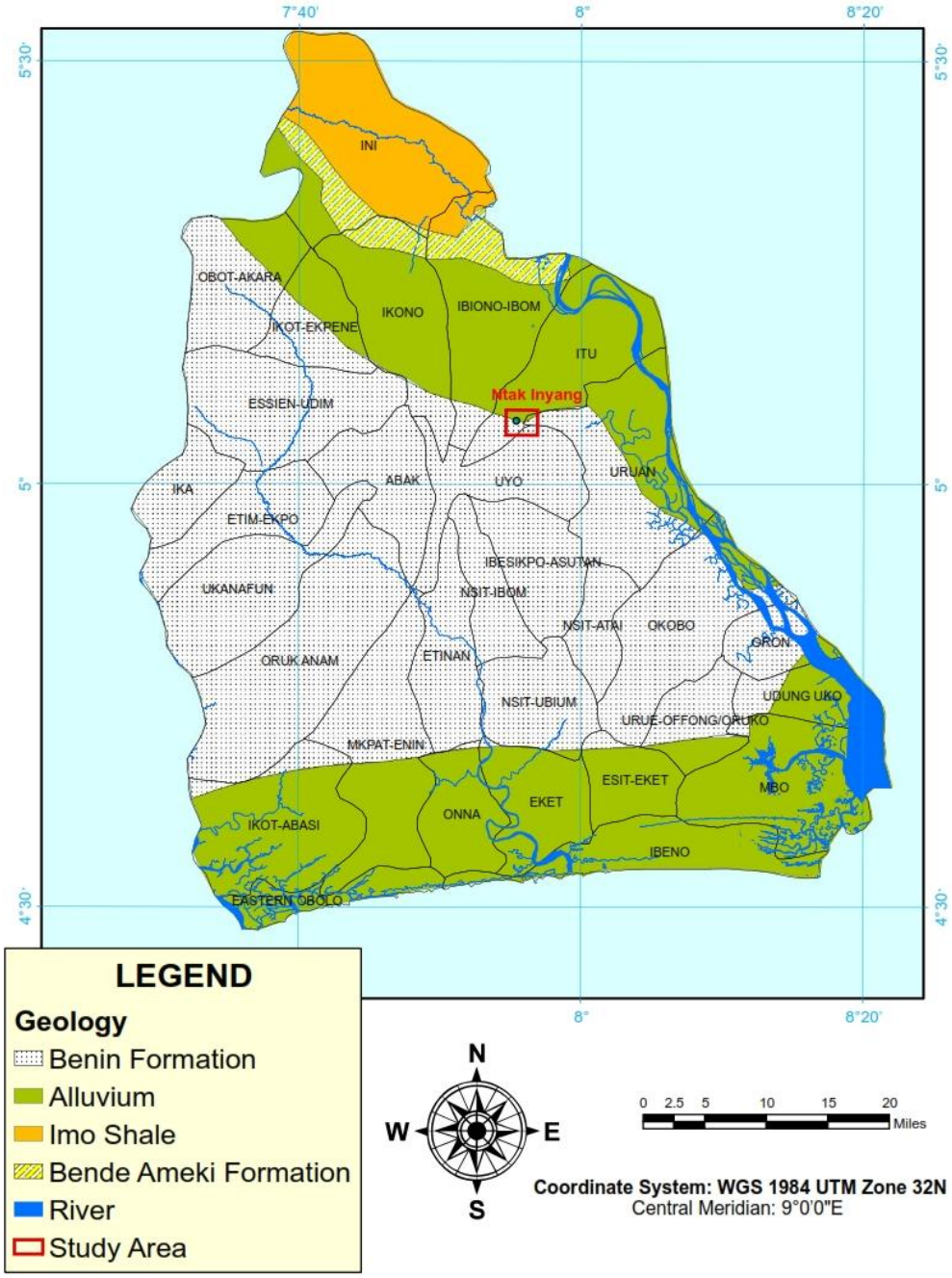


Figure 1: Geological Map of Akwa Ibom State Showing the Study Area

2.2 Laboratory Analysis

Preliminary tests were performed on six samples with result presented. In preparation of all specimens, the required amount of stabilizers by dry weight of soil was measured and mixed in the dry state before addition of water for any given test.

All tests were performed in accordance with BS1377 (1990) as mentioned above. Specimens for the unconfined compressive strength and the california bearing ratio were prepared at maximum dry density and optimum moisture content using BS compaction energy level.

2.3 Chemical Analysis

The machines used for the chemical test is called the Atomic Absorption Spectrometer (AAS). The sample is first passed through the digestion process which is done by measuring 100ml of the sample into a 125ml beaker, then 0.5ml of nitric acid (HNO_3) was added, then followed by the addition of 5ml of hydrochloric acid (HCL) to the beaker. The sample is then heated to a temperature of 90^{o}c for 2 hours, then allowed to cool

after which it is filtered to remove solid particles before taking the sample for testing on the Atomic Absorption Spectrometer. This equipment called Atomic Absorption Spectrometer is used to determine the elements in a substance. Atomic Absorption is the process that occurs when a ground state atom absorbs energy in the form of light of a specified wave length and is elevated substance is applied on the chopper and a beam of light from the lamp sent across the chopper which passes through the flame through the monochrometer to the detector before giving out a reading. The different elements have certain percentages to which they react to. For example, at 70% if there be the presence of Nickel in the substance, the machine will give a readout value. Here is a schematic representation for better understanding.

Lamp - Chopper - Flame - Monochrometer - Detector - Readout

2.4 Design and Analysis of Experiments

Literally, an experiment is a test. Researchers perform experiments in virtually all fields of inquiry, usually to discover something about a particular process or systems. More formally, an experiment is a test or series of tests in which purposeful changes are made to the input variables of a process or system so that we may observe and identify the reasons for the changes that may be observed in the output respond Montgomery *et al.* (2005). Experimentation plays an important role in product realization activities, which consist of new product design and formulation, manufacturing process development and process improvement. Experimentation is a vital part of the scientific or engineering method. Now there are certainly situations where the scientific phenomena are so well understood that useful results including mathematical models can be developed directly by applying these well understood principles Montgomery *et al.* (2005). However, most problems in science and in engineering require observation of the system at work and experimentation to elucidate information about why and how it works. Well designed experiments can often lead to a model of system performance, such experimentally determined models are called **empirical models**, he posited. In general, experiments are used to study the performance of processes and systems. The process under consideration can be as a combination of operations, machines, methods, people, materials and other resources that transforms some inputs (often a material) into an output that has one or more observable response variables. Some of the process variables and materials properties $x_1, x_2, \ldots x_p$ are controllable, whereas other variables $y_1, y_2, \ldots y_p$ are uncontrollable (although they may be controllable for purposes of a test).

2.5 Scheffe's Model

Interests among researchers have changed from determining which process variables affect the response to determine the region or the important factors that leads to the best possible response Montgomery 2005. The process of obtaining this response is termed response surface methods. Response surface methodology RSM is a collection of mathematical and statistical techniques useful for the analysis and modeling of problems in which a response of interest is influenced by several variables and the objective is to optimize this response Myers *et al.* (1997). The first step in the RSM is to find approximation for the true functional relationship between the response and a set of independent variables. If the response is well modelled by a linear function of the independent variables, then the approximating function is of the first order model Myers *et al.* (1997). This is given as:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \epsilon \qquad 2.51$$

And in compact form is expressed as:

$$y = \beta_0 + \sum_{i=1}^{K} \beta_i x_i \ldots\ldots + £ \qquad 2.52$$

Where,

y = Dependent variables

x = Independent variables

β_0= Model constant

β_0 (For i =1-k) =Independent variables

ε = Random error

If there is a curvature in the system then a polynomial of higher degree must be used such as the second order model:

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i x_{i^2} \sum \sum_{i<j}^{k} \beta_{ij} x_i x_j \ldots \epsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 3.53$$

Where,

β_0 = Interaction constant between independent components

The least square method (LSM) estimates the parameters in the polynomials. The response surface analysis is then performed using the fitted surface. If the fitted surface is an adequate approximation of the true response function then, analysis of the fitted surface will be approximately equal to the analysis of the actual system.

The method of steepest ascent is also one of the response surface methods Myers *et al.* (1997). It is a procedure for moving sequentially in the direction of the maximum increase in the response. In the case where

minimization is desired, the method is called the steepest descent and the fitted order model given in Equation (2.52). The challenge which any model developed using polynomials in Equation (2.51), (2.52) or (2.53) is that the developed model will always give an expected response, even when all the components are absent (zero). The limitation is due to the presence of the constant β_0 and random term, ε in the polynomials. Hence, models developed by the polynomials in Equation (2.51), (2.52) and (2.53) may not be reliable. Therefore, this research work will proffer systematic order to model development using Scheffe's model. In this approach, the constants in the polynomials are expressed implicitly as functions of the components of the mixture. Thus, the limitation inherent in the ordinary polynomial functions is overcome, leading to a reliable model.

2.6 Mixture Experiments

The major interest in any mixture experiments is to model the response and components relationship. Thereon, the major challenge lies on the use of suitable polynomial which will give a realistic prediction of this response component relation. Many products are mixtures of several components. Characteristics of the products such as the strength of steel, concrete, fibre, polymer etc depend only on the relative proportions of the components in the mixture properties caused by varying the ingredient proportions is the objective of performing mixture experiments Cornell 1991. In mixture experiments, the levels of individual components of the mixture are not independent Myers *et al.* (2004).

For example, if $x_1, x_2 \ldots x_p$ denote the proportions of p components of a mixture, then;

$0 \leq x_i \geq 1 \qquad i = 1, 2, \ldots, p$ (2.61)

And $x_1 + x_2 + \ldots x_p = 1$ (i.e 100%) (2.62)

With three components, p_i (i = 1, 2 ,3), the mixtures space is a triangle with vertices corresponding to formation that are pure blends (mixtures that are 100% of a single component)

2.6.1 Simplex Design:

Simplex is the structural representation (shape) of the line or planes joining the assumed positions of the constituent materials of the mixtures Obam 2006. They are used to study the effects of mixture components on the response variable. A (q, m) simplex lattice design for p components consist of points defined by the following coordinate setting; the proportions assumed by each component take the m + 1 equally spaced values from 0 to 1.

That is,

$$x_1 = 0, \frac{1}{m}, \frac{1}{m}, \ldots, 1 \qquad i = 1,2, \ldots, q \qquad (2.63)$$

Where,

Q = Number of components of the mixture

M= Maximum possible number of the components which the mixture can be composed of (Mixture level). For example, when q = 3 and m = 2; then, the possible number of runs is:

$(x_1, x_2, x_3,) = (1,0,0), (0,1,0), (0,0,1), (1/2, 1/2, 0), (1/2, 0, 1/2), (0, 1/2, 1/2)$ = 6 runs

These can be represented in a simplex lattice as show in Figure 2.

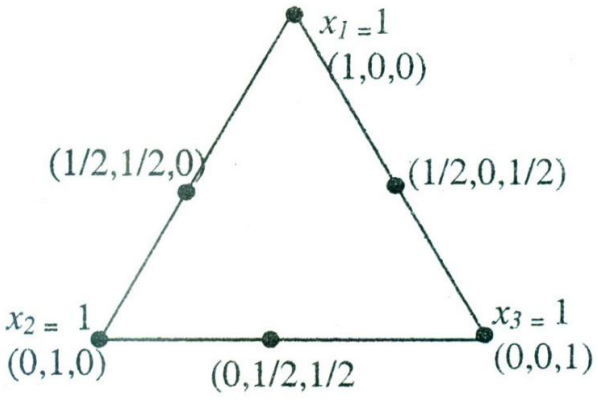
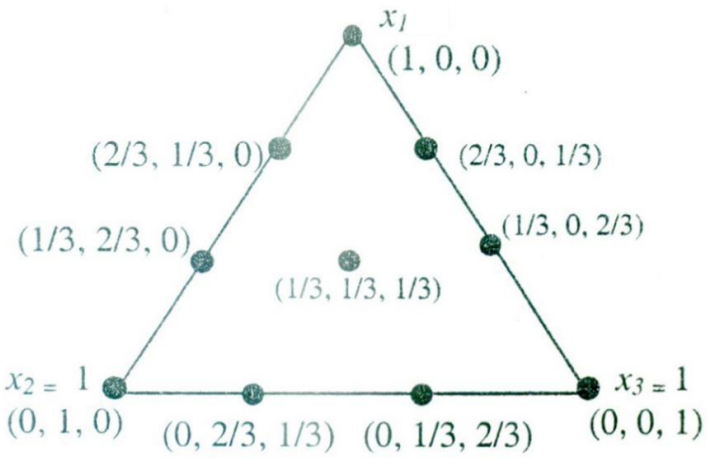


Figure 2: (3,2) Lattice Design

For a (3,3) lattice design, the number of runs is

$(x_1, (x_2, (x_3,) = (1,0,0); (0,1,0); 0,0,1); (1/3, 1/3, 1/3); (1/3, 0, 2/3); (2/3, 0, 1/3; (0, 1/3\, x_1,, 2/3);$
$(0, 2/3, 1/3); (1/3, 2/3, 0); (2/3, 1/3, 0) = 10$ runs

Figure 3: (3,3) Lattice Design



Simplex lattice design combinations (p, m) such as (4,2), (4,3), (4,4), (5,2), (5, 3) …… (i, j) for i=1,2,3, …q and j = 1,2, 3,…, m can be obtained. The combinations depend on the number of components of the mixture, q and the level of combination (mixture level or order of the lattice), m. in general, the number of points in a (q, m) simplex lattice design is given as:

$$N = \frac{(q+m-1)!}{M!(q-1)!} \quad (2.64)$$

Where

N= Number of points in a simplex lattice
Q = Number of components in the lattice
M= Order of the lattice

An alternative to simplex lattice design is simplex centroid design Scheffe 1963.

Mixture models differ from the usual polynomials employed in response surface work because of the constraint Scheffe 1958.

$$\sum x_1 = 1 \quad (2.65)$$

The standard forms of the mixture models (Scheffe's models) that are in widespread use are:

Linear:

$$E(y) = \sum_{i=1}^{p} \beta_i x_1 \quad (2.66)$$

Quadratic:

$$E(y) = \sum_{i=1}^{p} \beta_i x_1 + \sum \sum_{i<j}^{p} \beta_{ij} x_i x_j \quad (2.67)$$

Full cubic:

$$E(y) = \sum_{i=1}^{p} \beta_i x_1 + \sum \sum_{i<j}^{p} \beta_{ij} x_i x_j + \sum \sum_{i<j}^{p} \beta_{ij} x_i x_j \left(x_i - x_j\right) + \sum \sum \sum_{i<j<k}^{p} \beta_{ijk} x_x \quad (2.68)$$

Special cubic:

$$E(y) = \sum_{i=1}^{p} \beta_i x_1 \sum \sum_{i<j}^{p} \beta ij x_i x_j + \sum \sum \sum_{i<j<k}^{p} \beta_{ijk} x_x x_j x_k \quad (2.69)$$

Where,

β_i= Expected response to the pure blend, $x_i = 1$ and $x_j = 0$ when $i \neq j$

$E\ (y) =$ Expected response

The portion $\sum_{i=1}^{p} \beta_i x_i$ *is* called the linear blending portion. When curvature arises from nonlinear blending between component pairs, the parameters β_{ij} and β_{ijk} represent either synergistic or antagonistic blending. Higher order terms are frequently necessary in mixture models because the phenomena studies may be complex and the experimental region is frequently the entire operability region and are therefore large, requiring an elaborate models Montgomery 2005.

Mixture models which are also known as Scheffe's models from mere observation are distinct from ordinary polynomials by the absence of the random term and independent constant variables in the models.

2.6.2 Relationship Between The Pseudo And Actual Components

In Scheffe's mixture design, the Pseudo – components, X_i have relationship with actual components, S_i. The relationship between X and S as expressed by Scheffe (Scheffe, Experiments with Mixtures, 1958) is given as:

$$X = A \cdot S\ ;\ A = \frac{X}{S} \text{ or } A = S^{-1} \cdot X;\ S = \frac{X}{A} = X \cdot A^{-1} = S \cdot B \tag{2.6.10}$$

Where,

$A^{-1} = B$; A is the of the actual – pseudo proportionality coefficient

Equation (2.6.10) is used to determine actual component of the mixture when the Pseudo components are known, vice versa.

For q components and in keeping with the principle of absolute volume, the sum of the actual component mixture in a given factor space is giving as:

$$S = \sum_{i=1}^{q} S_i = S_1 + S_2 + S_3 + \ \ldots\ + S_{q-1} + = 1 \tag{2.6.11}$$

Dividing Equation (2.6.11) by the sum of the actual component mixture, we have:

$$\frac{S}{S} = \frac{S_1 + S_2 + S_3 + \ \ldots\ + S_{q-1} + S_q}{S} = \frac{S_1}{S} + \frac{S_2}{S} + \frac{S_3}{S} + \ \ldots + \frac{S_{q-1}}{S} + \frac{S_q}{S}$$

$$1 = Z_1 + Z_2 + Z_3 + \ \ldots\ + Z_{q-1} + Z_q \tag{2.6.12}$$

Where,

$\frac{S_1}{S} = Z_1;\ \frac{S_2}{S} = Z_2; \frac{S_3}{S} = Z_3; \frac{S_{q-1}}{S} = Z_{q-1};\ \frac{S_q}{S} = S_q$

In general form, for any factor space, we have:

$$Z_i = \frac{S_i}{S} (i\ =\ 1, 2, 3\ \ldots, q) \tag{2.6.13}$$

Equation (2.6.13) is the proportion of the i^{th} constituent component of any considered mixture design.

As in a general mixture problem, the measured response is assumed to depend only on the proportions of the ingredients in the mixture, not the amount of the mixture. Therefore, modelling, consequent on experimentation can be based on the actual and pseudo components. Thus, the transformation of the actual components, S_i into actual ratio components, Z_i is jettisoned (Oguaghamba and Mama, 2018).

Then, expressing the actual – pseudo proportionality coefficient expression (Equation (3.5.10)) in matrix form, we have;

$$[A] = \frac{[X]}{[S]} = [S]^{-1}[X] \tag{2.6.14}$$

Oguaghamba and Mama (2018) developed this expression to mean the inverse or transpose matrix of the actual components corresponding to the pure blend Pseudo – components of space points as follows:

$$[A] = [S]^{-1} = [S]^{T} \tag{2.6.15}$$

$$[A] = \begin{bmatrix} a_{1,1}\, a_{1,2}\, a_{1,3} \cdots a_{1,q} \\ a_{2,1}\, a_{2,2}\, a_{2,3} \cdots a_{2,q} \\ a_{3,1}\, a_{3,2}\, a_{3,3} \cdots a_{3,q} \\ \cdot \quad \cdot \quad \cdot \ \ldots\ \cdot \\ \cdot \quad \cdot \quad \cdot \ \ldots\ \cdot \\ \cdot \quad \cdot \quad \cdot \ \ldots\ \cdot \\ a_{N,1} a_{N,2} a_{N,3} \cdots a_{N,q} \end{bmatrix} = \begin{bmatrix} s_{1,1}\, s_{1,2}\, s_{1,3} \cdots s_{1,q} \\ s_{2,1}\, s_{2,2}\, s_{2,3} \cdots s_{2,q} \\ s_{3,1}\, s_{3,2}\, s_{33}, \cdots s_{3,q} \\ \cdot \quad \cdot \quad \cdot \ \ldots\ \cdot \\ \cdot \quad \cdot \quad \cdot \ \ldots\ \cdot \\ \cdot \quad \cdot \quad \cdot \ \ldots\ \cdot \\ s_{N,1} s_{N,2} s_{N,3} \cdots s_{N,q} \end{bmatrix}^{T} = \begin{bmatrix} s_{1,1} s_{2,1} s_{3,1} \cdots s_{N,1} \\ s_{1,2} s_{2,2} s_{3,2} \cdots s_{N,2} \\ s_{1,3} s_{2,3} s_{3,3} \cdots s_{N,3} \\ \cdot \quad \cdot \quad \cdot \ \ldots\ \cdot \\ \cdot \quad \cdot \quad \cdot \ \ldots\ \cdot \\ \cdot \quad \cdot \quad \cdot \ \ldots\ \cdot \\ s_{1,q} s_{2,q} s_{3,q} \cdots s_{N,q} \end{bmatrix} \tag{2.6.16}$$

2.6.3 Determination of Actual Components of the Nonlinear Blending Mixture, $S'_{N,q}$

Oguaghamba and Mama (2018) gave the expression for the other actual components of the binary mixture, $S'_{N,q}$ for the remaining N – q factor points as:

$$\begin{bmatrix} S'_{N,1} \\ S'_{N,2} \\ S'_{N,3} \\ \cdot \\ \cdot \\ \cdot \\ S'_{N,q} \end{bmatrix} = \begin{bmatrix} s_{1,1} s_{2,1} s_{3,1} \cdots s_{N,1} \\ s_{1,2} s_{2,2} s_{3,2} \cdots s_{N,2} \\ s_{1,3} s_{2,3} s_{3,3} \cdots s_{N,3} \\ \cdot \quad \cdot \quad \cdot \ \ldots\ \cdot \\ \cdot \quad \cdot \quad \cdot \ \ldots\ \cdot \\ \cdot \quad \cdot \quad \cdot \ \ldots\ \cdot \\ s_{1,q} s_{2,q} s_{3,q} \cdots s_{N,q} \end{bmatrix} \times \begin{bmatrix} X_{N,1} X_{N,2} X_{N,3} & \cdot \cdot \cdot & X_{N,q} \end{bmatrix}^{T}$$

$$\left[S'_{N,q}\right] = [A] \cdot \left[X_{N,q}\right]^{T} = [S] \cdot \left[X_{N,q}\right]^{T} \tag{2.6.17}$$

These derived actual components corresponding to the remaining N – q lattice points of the pseudo – components mixture proportions are used as other mixture proportion in the experimentation to obtained their corresponding responses.

2.6.4 Generalized Scheffe's Second Degree Mathematical Models

Scheffe's Models are most times referred to as the mixture models. They differ from the usual regression model due to the correlation between all the components in the mixture designs. Another difference is that the intercept term in the model is not usually included in the regression model (Oguaghamba and Mama, 2018).

The standard form of the quadratic mixture model according to Scheffe (1958) is given as:

Quadratic Model: $E(y) = \sum_{i=1}^{q} \beta_i x_i + \sum \sum_{i<j}^{q} \beta_{ij} x_i x_j$ (2.6.18)

Where,

β_i= linear blending portion due to the pure blend, $X_i = 1$ and $X_j = 0$; $i \neq j \neq k$; $E(y) =$ Expected response. β_{ij} represents the quadratic nonlinear blending between component pairs, whose parameters may be either synergistic or antagonistic blending. β_{ijk} Represents the full cubic nonlinear blending among component sets of 3, whose parameters may be either synergistic or antagonistic blending.

Oguaghamba and Mama (2018) gave the generalized Scheffe's model for the second degree – q variables mixture lattice {q,2} as follows:

$$E(y) = y_1X_1(2X_1 - 1) + y_2X_2(2X_2 - 1) + y_3X_3(2X_3 - 1) + \cdots + y_{q-1}x_{q-1}(2X_{q-1} - 1) + \cdots + y_qx_q(2X_q - 1) + 4y_{12}X_1X_2 + 4y_{13}X_1X_3 + 4y_{23}X_2X_3 + 4y_{(q-1),q}x_{q-1} \quad (2.6.19)$$

The term, y_i and y_{ij} correspond to the mixture response at the respective space points i and ij of the actual pure blend, S_i for i = 1, 2, 3, …, q (principal points); and derived actual binary blend, S_{ij} (derived mix ratio) in Equation (2.6.24) obtained from the laboratory experiments.

2.6.5 Model Validation and Adequacy

Model validation is carried out in two ways, (a) either by randomly splitting an existing data set into two parts, and using part of the data for model fitting, and part of the data for model validation or (b) using one full data set for model fitting, and finding a second independent data set for model validation. The latter approach is adopted in Scheffe's model and validation (Oguaghamba and Mama, (2018)).

Therefore, the model Equation (2.6.19) is tested for adequacy against the experimental results using a new set of design points. These new set of mixture design proportions (now referred to as control mixture design points) are determined in similar manner the binary mixture proportions are determined in the main experiments. The only new set of parameters introduced is the control Pseudo – components.

Prior to this, a statistical hypothesis for this Scheffe's model would have been stated earlier. That is, the NULL HYPOTHESIS, H_o and the ALTERNATE HYPOTHESIS, H_A. Null hypothesis claims that there is no significant difference between specified Scheffe's model responses and the experimental responses for any other independent actual component mixtures (such as those the control mixtures). Whereas, the alternate hypothesis is against the statement (i.e. there is significant difference between specified Scheffe's model responses and the experimental responses for any other independent actual component mixtures (such as those the control mixtures).

These hypotheses are tested at a specified significance level, α, which represents the maximum tolerable risk of incorrectly rejecting the null hypothesis, H_o. Among tests used to check significant levels of difference between model and experimental responses include Student's t – Test, Fisher's F – Test, etc.

2.6.6 Student's t – Test Method

The t – Test (also called Student's t – Test) compares two "means" and tells if they are different from each other. The t – test also defines how significant the differences are. In other words, it lets reveals if those differences could have happened by chance (Oguaghamba and Mama, 2018).

Oguaghamba and Mama (2018) gave an advance and simpler expression for obtaining the t – test variance in experimental response as follows:

$$t = \frac{\sqrt{(N-1)} \times \sum(Y_m - Y_e)}{\sqrt{(N\sum(Y_m - Y_e)^2 - (\sum(Y_m - Y_e))^2)}} \quad (2.6.20)$$

where,

Y_e and Y_m are the average experimental and model responses respectively

N is total design points in the control experiments, t is the variance from the t – statistics.

The t – value obtained in Equation (2.6.20) is compared with the one from the standard statistical table according to Dougherty (2002) at enhanced (α/N) significant level and degree of freedom, V_e. That is, $t_{(\alpha/N)}(v_e)$. When the t – value from the standard statistical table, $t_{(\alpha/N)}(v_e)$ is greater than those of the t - values obtained in Equation (2.6.20), the Null hypothesis is accepted and the model is adequate. Otherwise, the Null hypothesis is rejected, the Alternate hypothesis is accepted and the model is not adequate.

2.6.7 *F* – Statistics (Fisher's) Test Method

This test compares the variance from the model response, S_i with that from the experimental responses. The equation for Fisher's test is given as:

$$F = \frac{\text{explained variance}}{\text{unexplained variance}} \frac{S_1^2}{S_2^2} \quad (2.6.21)$$

where,

$$S_1^2 \text{ or } S_2^2 = S_e^2 = \frac{\sum(Y_e - \bar{y}_e)^2}{N-1};\ S_1^2 \text{ or } S_2^2 = S_m^2 = \frac{\sum(Y_m - \bar{y}_m)^2}{N-1};\ \bar{y}_e = \frac{\sum Y_e}{N};\ \bar{y}_m = \frac{\sum Y_m}{N} \quad (2.6.22)$$

S_1^2 is the greater of S_e^2 and S_m^2; S_2^2 is smaller of the S_e^2 and S_m^2

S_e^2 and S_m^2 are variances from are experimental and model responses

Y_e and Y_m are experimental and model responses; $\bar{y}_e$ and $\bar{y}_m$ are mean values of experimental and model responses; N is the sample group or total control space points.

$$N - k = V_e \text{(Degree of freedom of design points)} \quad (2.6.23)$$

Fisher's tests the adequacy of the model by comparing the responses of the experimental and model results in the control sample group. The Null Hypothesis is accepted and Alternative Hypothesis rejected if and only if:

$$\frac{1}{F_{\alpha(v_1,v_2)}} < F < F_{\alpha(v_1,v_2)} \quad (2.6.24)$$

Where,

Dougherty (2002) gave critical values of the $F_{\alpha(v_1,v_2)}$ distribution in which α and N have their usual meaning; v_1 and v_2 are the number of degrees of freedom defined in Equation (2.6.23).

III. RESULTS AND DISCUSSION

Table 1.0: Results of Chemical Analysis of Processed Coconut Shell Ash

Oxides	CaO	SiO_2	AL_2O_3	K_2O	Na_2O	Fe_zO_3	MgO	LOI	MnO
Processed Coconut shell Ash (%)	51.34	7.31	15.41	5.73	29.88	6.18	35.89	4.06	2.92

Table 2.0: Soil Test Summary Result for Processed Coconut Shell Ash

Test	Soil sample (Clay)	2%	4%	7%	3%	4.5%	5.5%
Sieve Analysis	60.00						
OMC	15.36	16.13	17.52	18.42	18.69	19.65	20.22
MDD	1.61	1.66	1.73	1.78	1.85	1.87	1.92
LL	50.40	44	40	30	33	35	39
PL	32.00	24	28	20	18	23	28
PI	18.40	20	12	10	15	12	11
CBR(soak)	21.00	23	28	33	29	26	24
CBR(unsoak)	32.07	34	36	41	33	30	25
UCS	392.77						
G_s	2.21						
AASHTO CLASS	A-2-5						
UNIFIED CLASS	CL						
CONSISTENCY	>384(stiff)						
COLOUR	Dark						

From Table 2.0, the value of OMC increase from 15.36% to 20.22% while the value of MDD also increase from 1.6gm/cm^3 to 1.92gm/cm^3. The ,liquid limit and plasticity index also decreases from 50.40% to 30% and from 18.40% to 10% respectively, though showed a slight increase thereafter for both properties with addition of processed Coconut Shell Ash content. The CBR values for unsoak and soak also increases from 32.07% to 41% and from 21% to 33% respectively and later decreased significantly with addition of stabilizer. The UCS values increased significantly with addition of percentage stabilizer from 392.77KN/m^2 to 446.25kN/m^2 at 0% to 7% and then decreased in value from 396.16kN/m^2 to 120.56kN/m^2 at 3% to 5.5% additive.

3.1 Identification of Soil and Processed Coconut Shell Ash

The result in Table 1.0, shows the combined percentage of SiO_2, Al_2O_3, CaO, MgO and Fe_2O_3 of the Processed Coconut Shell Ash is 126.98% which satisfies and is above the minimum requirement value of 58% specified for local pozzolanic material, MgO composition was found to be 25.65% which is above the 20% minimum requirement, while CaO composition was 52.04% and is within Samuel Assam's recommended minimum range of 51% for local stabilizers. The loss on ignition showed the extent of carbonation in sample of processed oyster shell ash during the test, the value obtained was 4.07% which is less than 7%, the maximum

value required for pozzolan. It means that most of the sample where absorbed by the system and the sample contains very little carbon. The composition of calcium alone is 52.04% and is responsible for the ion exchange between soil and the processed coconut shell ash resulting in the formation of more granular material and strength development. The index properties of the natural soil before addition of various percentages of processed coconut shell ash presented in Table 2.0, showed that the engineering and geotechnical properties of the natural soil, liquid limit is 50.40%, plastic limit is 32.00%, plastic index is 18.40% while the CBR and UCS values are 32.07% and 392.77kN/m^2 respectively. In its natural state, the soil is not suitable for use as filled material for subbase but requires some level of improvement before it can be used as a subbase material based on **Clause 6201** of the General Specification (Road and Bridges) **Vol. II 1994.**

The relationship between MDD and Processed Coconut Shell Ash content is shown in Figure 8. The results indicate that from 0% to 7% Processed Coconut Shell Ash content, the MDD increased from 1.61gm/cm^3 to 1.98gm/cm^3 respectively. This slight significant increase in value of the MDD was as a result of the Processed Coconut Shell Ash occupying the small voids within the soil matrix. It may also be as a result of the high specific gravity of the soil sample.

Figure 7 shows the variation of OMC with Processed Coconut Shell Ash content. The result shows that the OMC increased with increase in Processed Coconut Shell Ash content. The increase may be attributed to the additional water molecule needed to coat the surface area and to lubricate entire soil matrix for hydration process (Eze-Uzomaka *et al.* 2010).

Variation of liquid limit with Processed Coconut Shell Ash is shown in Figure 4. The liquid limit decreased from (50.4-28.0)% with addition of Processed Coconut Shell Ash from 0% to 7% respectively. The decreased may be as a result of the calcium silicate present in the stabilizer, due to high content of calcium and silicate ions. This chemical compound will react with the hydroxide in the clay resulting in the flocculation and aggregation of the soil particles. Figure 5 shows the relationship between plastic limit and Processed Coconut Shell Ash. The plastic limit results showed that the PL value decreased from 32% to 22.20% from 0% to 7% addition of PCSA. The reason for the variation is that the PCSA is not highly plastic when compared to clay that is, the plastic content is minimal and as such when added to the clay soil which is highly plastic, the paste in the soil sample is improved as the voids is occupied by POSA content in required proportion. This may also be attributed to the presence of Magnesium and Calcium oxide present in the soil matrix resulting in aggregation of the soil particles.

The variation of plasticity index with Processed Coconut Shell Ash is presented in Figure 6. The result shows that the PI value increases and decreases with increase amount of stabilizer and results obtained was within the stipulated requirement for use as subbase material **Clause 6201** of the General Specification (Road and Bridges) **Vol. II 1994**. The reason for this significant changes may be as a result of the replacement of the finer soil particles with PCSA with subsequent reduction in plasticity index (Okafor, 2009)

The relationship between CBR and Processed Coconut Shell Ash content is presented in Figure 9. The result shows that the CBR for unsoak sample increased from 0% to 15% with a value of 32.07% to 45% respectively and slight fluctuation in value from 33% to 41% at 20% to 30% varying amount of Processed Coconut Shell Ash content. The increment in CBR value may be attributed to the gradual formation of calcium silicate compounds and magnesium oxides in the PCSA reacting with some calcium hydroxide present in the soil (clay). The trend observed with soak CBR is similar to the unsoak though with relatively lower values.

The variation of UCS with Processed Coconut Shell Ash content is shown in Figure 11. The UCS values increases and decreases with varying amount of PCSA content from 0% to 30%. From 0% to 15% the value of UCS increases from 410.77kN/m^2 to 418.01kN/m^2 respectively, while the value decreases from 324.22kN/m^2 to 369.50kN/m^2 at 20% to 25%, though increases again at 30% added PCSA content. The increase in strength is attributed to the formation of calcium silicate compounds between the calcium and magnesium hydroxide present in the soil and the Processed Coconut Shell Ash.

3.2 Scheffe's Second Degree Model for Ntak-Uyo Clay Subgrade

3.2.1 Model formulation for Ntak – Uyo Clay Subgrade

Based on the characteristics strength of information of the variation of proportions of the stabilizing additives, the pure mixture proportions in Table 3.0 were selected based on experience of past and previous knowledge of use of additive in soil stabilization technique. They form the basis for the scheffe's model development. The pure blends of their pseudo – components are assumed to correspond to these actual components.

Table 3.0: Pure Blend Pseudo and Actual Components for Scheffe's (3,2) Lattice

		Actual Components			Expected response	Pseudo Components		
N	Points on Factor Space	S_1 POSA	S_2 Water	S_3 Soil	Y	X_1 POSA	X_2 Water	X_3 Soil

1	A_1	2	3	95	Y_1	1	0	0
2	A_2	4	6	90	Y_2	0	1	0
3	A_3	7	8	85	Y_3	0	0	1

Using equation (2.6.17), the coefficient of the relationship of actual and pseudo components in matrix form is obtained as:

$$[A] = [S] = \begin{bmatrix} S_{11} & S_{21} & S_{31} \\ S_{12} & S_{22} & S_{32} \\ S_{13} & S_{23} & S_{33} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{bmatrix}^T = \begin{bmatrix} 2 & 3 & 95 \\ 4 & 6 & 90 \\ 7 & 8 & 85 \end{bmatrix}^T = \begin{bmatrix} 2 & 4 & 7 \\ 3 & 6 & 8 \\ 95 & 90 & 85 \end{bmatrix}$$

From equation (2.63), for second degree space lattice (M=Z), the simplex coordinate, x_i is given as: $x_i = 0, \frac{1}{m}, \frac{2}{m}, \ldots, 1$; $x_i = 0, \frac{1}{2}, \frac{2}{2}, \ldots, 1 = 0, 0.5 \; and \; 1$

In a three variable and second degree scheffe's polynomial and using equation (2.64), the design space points is obtained as: Design space points, $N = \frac{(q+m-1)}{m!(q-1)!} = \frac{(3+2-)!}{2!(3-1)!} = 6 \; runs$ of experiment. The remaining design space points to make up the six design space points are in the order of the coded variables are given in the Table 4.0. As in the control experiment, **Oguaghamba and Mama (2018)** explained that the design space points are made of binary mixture and coded arbitrary but must be constrained to sum to unity. Design points 7 – 9 are added up to be used as control points.

Table 4.0: Binary blend Pseudo and Actual components for Scheffe's (3, 2) Lattice

N		Actual Components			Expected Response	Pseudo Components		
	Points on Factor Space	S_1 POSA	S_2 Water	S_3 Soil	Y	X_1 POSA	X_2 Water	X_3 Soil
4	A_{12}	$S'_{4,1}$	$S'_{4,2}$	$S'_{4,3}$	Y_1	0.5	0.5	0
5	A_{13}	$S'_{5,1}$	$S'_{5,2}$	$S'_{5,3}$	Y_2	0.5	0	0.5
6	A_{23}	$S'_{6,1}$	$S'_{6,2}$	$S'_{6,3}$	Y_3	0	0.5	0.5
Control Experiment								
7	C_1	$S'_{7,1}$	$S'_{7,2}$	$S'_{7,3}$	C_1	0.25	0.25	0.5
8	C_2	$S'_{8,1}$	$S'_{8,2}$	$S'_{8,3}$	C_2	0.25	0.5	0.25
9	C_3	$S'_{9,1}$	$S'_{9,2}$	$S'_{9,3}$	C_3	0.5	0.25	0.25

Using equation (2.6.17), the actual components of the binary mixture, $S'_{N,q}$ is obtained as follows:

$$\begin{bmatrix} S'_{N,1} \\ S'_{N,2} \\ S'_{N,3} \end{bmatrix} = \begin{bmatrix} S_{1,1} & S_{2,1} & S_{3,1} \\ S_{1,2} & S_{2,2} & S_{3,2} \\ S_{1,3} & S_{2,3} & S_{3,3} \end{bmatrix} X \begin{bmatrix} X_{N,1} \\ X_{N,2} \\ X_{N,3} \end{bmatrix}$$

$$\begin{bmatrix} S'_{4,1} \\ S'_{4,2} \\ S'_{4,3} \end{bmatrix} = \begin{bmatrix} 2 & 4 & 7 \\ 3 & 6 & 8 \\ 95 & 90 & 85 \end{bmatrix} X \begin{bmatrix} 0.50 \\ 0.50 \\ 0.00 \end{bmatrix} = \begin{bmatrix} 3.00 \\ 4.50 \\ 92.50 \end{bmatrix}$$

$$\begin{bmatrix} S'_{5,1} \\ S'_{5,2} \\ S'_{5,3} \end{bmatrix} = \begin{bmatrix} 2 & 4 & 7 \\ 3 & 6 & 8 \\ 95 & 90 & 85 \end{bmatrix} X \begin{bmatrix} 0.50 \\ 0.00 \\ 0.50 \end{bmatrix} = \begin{bmatrix} 4.50 \\ 5.50 \\ 90.00 \end{bmatrix}$$

$$\begin{bmatrix} S'_{6,1} \\ S'_{6,2} \\ S'_{6,3} \end{bmatrix} = \begin{bmatrix} 2 & 4 & 7 \\ 3 & 6 & 8 \\ 95 & 90 & 85 \end{bmatrix} X \begin{bmatrix} 0.00 \\ 0.50 \\ 0.50 \end{bmatrix} = \begin{bmatrix} 5.50 \\ 7.00 \\ 87.50 \end{bmatrix}$$

$$\begin{bmatrix} S'_{7,1} \\ S'_{7,2} \\ S'_{7,3} \end{bmatrix} = \begin{bmatrix} 2 & 4 & 7 \\ 3 & 6 & 8 \\ 95 & 90 & 85 \end{bmatrix} X \begin{bmatrix} 0.25 \\ 0.25 \\ 0.50 \end{bmatrix} = \begin{bmatrix} 5.00 \\ 6.25 \\ 88.75 \end{bmatrix}$$

$$\begin{bmatrix} S'_{8,1} \\ S'_{8,2} \\ S'_{8,3} \end{bmatrix} = \begin{bmatrix} 2 & 4 & 7 \\ 3 & 6 & 8 \\ 95 & 90 & 85 \end{bmatrix} X \begin{bmatrix} 0.25 \\ 0.50 \\ 0.25 \end{bmatrix} = \begin{bmatrix} 4.25 \\ 5.75 \\ 90.00 \end{bmatrix}$$

$$\begin{bmatrix} S'_{9,1} \\ S'_{9,2} \\ S'_{9,3} \end{bmatrix} = \begin{bmatrix} 2 & 4 & 7 \\ 3 & 6 & 8 \\ 95 & 90 & 85 \end{bmatrix} X \begin{bmatrix} 0.50 \\ 0.25 \\ 0.25 \end{bmatrix} = \begin{bmatrix} 3.75 \\ 5.00 \\ 91.25 \end{bmatrix}$$

With these pure and binary mixture proportions in Table 3.0 and 4.0, as represented in Table 5.0, experimental test are conducted, the results are given as in Table 6.0

Table 5.0: Binary Blend Pseudo and Actual Components for Scheffe's (3,2) Lattice

		Actual Components			Expected Response	Pseudo Components		
N	Points on Factor Space	S_1 PCSA	S_2 Water	S_3 Soil	Y	X_1 PCSA	X_2 Water	X_3 Soil
1	A_1	2	3	95	Y_1=34	1	0	0
2	A_2	4	6	90	Y_2=36	0	1	0
3	A_3	7	8	85	Y_3=41	0	0	1
4	A_{12}	3	4.5	92.5	Y_{12}	0.5	0.5	0
5	A_{13}	4.5	5.5	90	Y_{13}	0.5	0	0.5
6	A_{23}	5.5	7	87.5	Y_{23}	0	0.5	0.5
				Control Experiment				
7	C_1	5	6.25	88.75	C_1	0.25	0.25	0.5
8	C_2	4.25	5.75	90	C_2	0.25	0.5	0.25
9	C_3	3.75	5	91.25	C_3	0.5	0.25	0.25

Table 6.0: California Bearing Ratio and Unconfined Compressive Strength Value Corresponding to the Design Space Points/Lattice

N	Points on Factor Space	CBR(unsaok) (%)	CBR(soak) (%)	UCS (kN/m^2)	Scheffe's (3,2) Lattice Coefficients, y_i and y_{ij}
1	A_1	34	23	445.20	y_1
2	A_2	36	28	445.59	y_2
3	A_3	41	33	446.25	y_3
4	A_{12}	33	29	396.16	y_{12}
5	A_{13}	30	26	326.27	y_{13}
6	A_{23}	25	24	120.56	y_{23}
7	C_1	27.05	25.89	211.13	
8	C_2	27.11	25.83	228.54	
9	C_3	28.14	25.82	279.87	

Similarly, for (3,2) space lattice, for q=3, equation (2.6.19) transforms as follows:

E(y) =

$$y_1x_1(2x_1-1)+\ y_2x_2\ (2x_2-1)+\ y_3x_3\ (2x_3-1)+\ 4y_{12}x_1x_2+4y_{13}x_1x_3+\ 4y_{23}x_2x_3 \qquad (2.6.25)$$

Substituting the coefficients, y_i and y_{ij} into equation (2.6.25), we have:

$y_{CBR(unsoak)}$ =

$$34x_1(2x_1-1)+36x_2(2x_2-1)+41x_3(2x_3-1)+132x_1x_2+120x_1x_3+\ 100x_2x_3 \qquad (2.6.26)$$

$y_{CBR(soak)}$ =

$$23x_1(2x_1-1)+28x_2(2x_2-1)+33x_3(2x_3-1)+116x_1x_2+104x_1x_3+\ 96x_2x_3 \qquad (2.6.27)$$

$y_{ucs(7days)}$ =

$$445.20x_1(2x_1-1)+445.59x_2(2x_2-1)+446.25x_3(2x_3-1)+1584.64x_1x_2+1305.08x_1x_3+\ 482.24x_2x_3 \qquad (2.6.28)$$

Table 7.0: Student *t*-Test Variables for CBR and UCS Responses

N	CBR(unsoak)(%)				CBR(soak)(%)				UCS(7days)(kN/m^2)			
	Y_e	Y_m	Y_m -$\bar{Y}_e$	$(Y_m$-$\bar{Y}_e)^2$	Y_e	Y_m	Y_m -$\bar{Y}_e$	$(Y_m$-$\bar{Y}_e)^2$	Y_e	Y_m	Y_m -$\bar{Y}_e$	$((Y_m$-$\bar{Y}_e)^2$
C_1	27.05	27	-0.05	0.0025	25.89	25.88	-0.01	0.0001	211.13	211.11	-0.02	0.0004
C_2	27.11	27.13	0.02	0.0004	25.83	25.87	0.04	0.0016	228.54	228.50	-0.04	0.0016
C_3	28.14	28.12	-0.02	0.0004	25.82	25.85	0.03	0.0009	279.87	279.88	0.01	0.0001
Sum	82.30	82.25	-0.05	0.033	77.54	77.60	0.06	0.0026	719.51	719.49	-0.05	0.0021
Mean ($\bar{Y}$)	27.43	27.42			25.85	25.87			239.84	239.83		

Similarly, recall equation (2.6.20) and by substitution we have;

$$t_{CBR(unsoak)} = \frac{\sqrt{(3-1)}x\ (-0.05)}{\sqrt{(3x(0.0033)-(-0.05)^2)}} = \frac{-0.070710678}{\sqrt{(0.0099-0.0025)}} = \frac{-0.070710678}{0.086023252} = -0.8220 = t_{calculate}$$

Since $t_{cal} < t\propto_{/N}; (Ve); (ie) - 0.8220 < 2.92$, we accept result.

$t_{CBR(soak)} = \frac{\sqrt{(3-1)}x\ (0.06)}{\sqrt{(3x(0.0026)-(-0.06)^2)}} = \frac{0.084852813}{\sqrt{(0.0078-0.0036)}} = \frac{0.084852813}{0.064807406} = 1.3093$

Since the result above, $t_{cal} < t\propto_{/N}(Ve)$; (ie) 1.3093 < 2.92 we accept results

Finally;

$t_{UCS(7days)} = \frac{\sqrt{(3-1)}x\ (-0.05)}{\sqrt{(3x(0.0021)-(-0.05)^2)}} = \frac{-0.070710678}{\sqrt{(0.0063-0.0025)}} = \frac{-0.070710678}{0.06164414} = -1.1471 = t_{cal}$

From the result, -1.1471 < 2.92, we have accept results

Table 8.0: Fisher's *F*-Test Variables for CBR Response

N	CBR(unsoak) (%)					
	Y_e	Y_m	$Y_e - \bar{Y}_e$	$(Y_e - \bar{Y}_e)^2$	$Y_m - \bar{Y}_m$	$(Y_m - \bar{Y}_m)^2$
C_1	27.05	27	-0.38	0.1444	-0.42	0.1764
C_2	27.11	27.13	-0.32	0.1024	-0.29	0.0841
C_3	28.14	28.12	0.71	0.49	0.7	0.49
Sum	82.30	82.25		0.7368		0.7505
Mean ($\bar{Y}$)	27.43	27.42				
CBR(soak) (%)						
C_1	25.89	25.88	0.04	0.0016	0.02	0.0004
C_2	25.83	25.87	-0.02	0.0004	0.01	0.0001
C_3	25.82	25.85	-0.03	0.0009	-0.01	0.0001
Sum	77.54	77.60		0.0029		0.0006
Mean ($\bar{Y}$)	25.85	25.86				

Table 9.0: Fisher's *F*-Test Variables for UCS Response

N	UCS(kN/m^2) (%)					
	Y_e	Y_m	$Y_e - \bar{Y}_e$	$(Y_e - \bar{Y}_e)^2$	$Y_m - \bar{Y}_m$	$(Y_m - \bar{Y}_m)^2$
C1	211.13	211.11	-28.71	824.641	-28.72	824.8384
C2	258.54	258.50	18.7	394.69	18.67	348.5689
C3	279.87	279.87	40.03	1,602.4009	40.04	1,603.2016
Sum	719.51	719.49		2,821.7319		2,776.6089
Mean ($\bar{Y}$)	239.84	239.83				

Recall equation (2.6.21); considering Table 8.0

$S_1^2 = S_e^2 = \frac{0.7368}{3-1} = 0.3684$

$S_2^2 = S_m^2 = \frac{0.7505}{3-1} = 0.37525$

$F_{CBR(unsoak)} \frac{S_1^2}{S_2^2} = \frac{0.3684}{0.37525} = 0.9817$

Since, 0.0526 < 0.9817 < 19.0, falls within the region, we accept result.

For $_{CBR(soak)}$, we have;

$S_1^2 = S_e^2 = \frac{0.0029}{3-1} = 0.00145$

$S_2^2 = S_m^2 = \frac{0.0006}{3-1} = 0.0003$

$F_{CBR(soak)} \frac{S_1^2}{S_2^2} = \frac{0.00145}{0.0003} = 4.8333$

Since 0.0526 < 4.8333 < 19.0, we accept result.

Also considering Table 9.0

$F_{UCS(7days)} = S_1^2 = S_e^2 = \frac{2,821.7319}{2} = 1,410.866$

$S_2^2 = S_m^2 = \frac{2,776.6089}{2} = 1,388.304$

So therefore; $F_{UCS(7days)} \frac{S_1^2}{S_2^2} = \frac{1410866}{1388304} = 1.0163$

Hence, 0.0526 < 1.0163 < 19.0, result accepted.

Table 6.0 shows the values of California bearing ratio (CBR) for unsoak and soak samples followed by unconfined compressive strength (UCS) obtained from laboratory test at different percentage of PPSA contents. **Figure 4 to 11** shows the relationship and the variation between the PPSA percentage content with the engineering and the geotechnical properties of the soil.

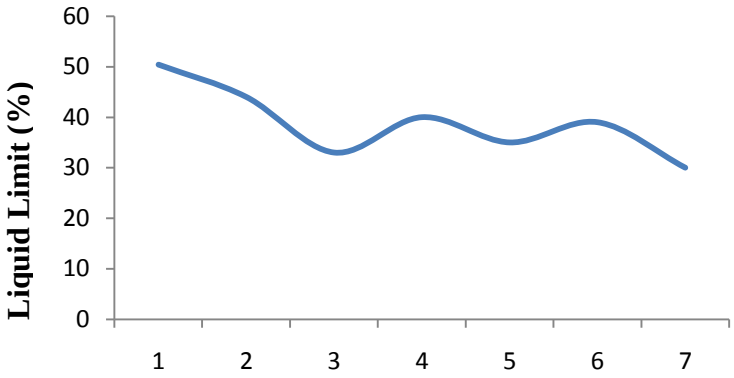


Figure 4: PCSA Content (%)

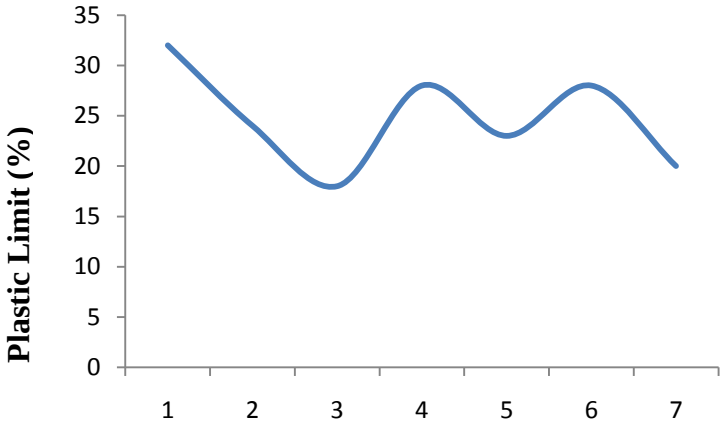


Figure 5: PCSA Content (%)

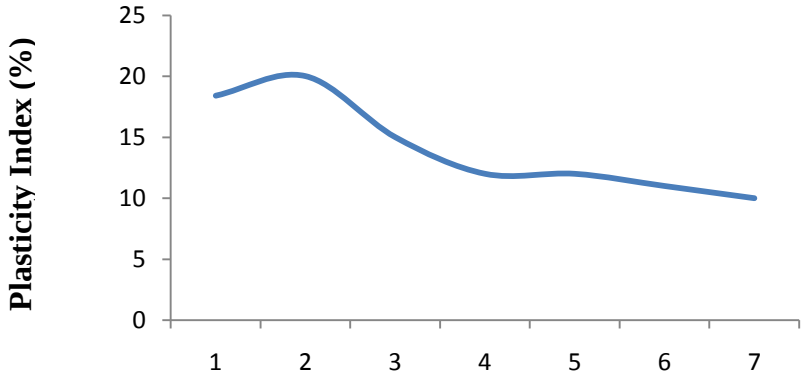


Figure 6: PCSA Content (%)

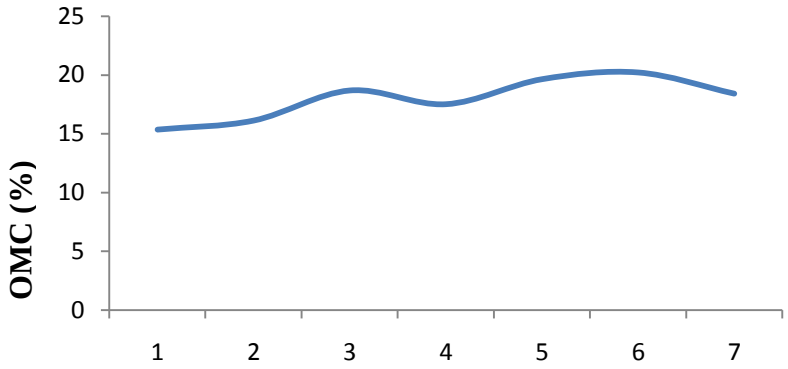


Figure 7: PCSA Content (%)

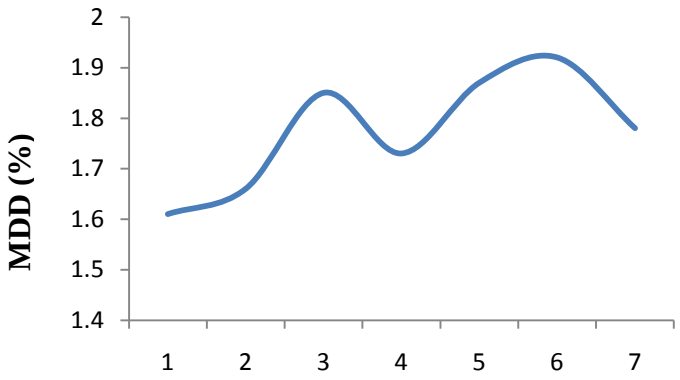


Figure 8: PCSA Content (%)

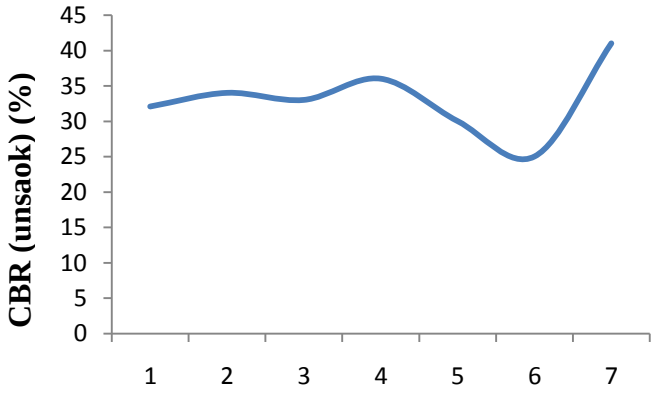


Figure 9: PCSA Content (%)

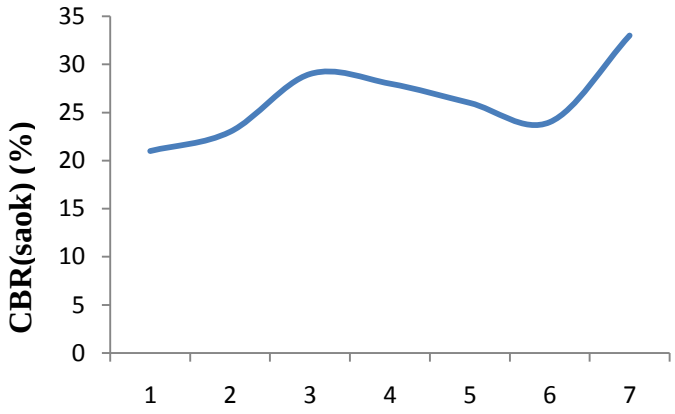


Figure 10: PCSA Content (%)

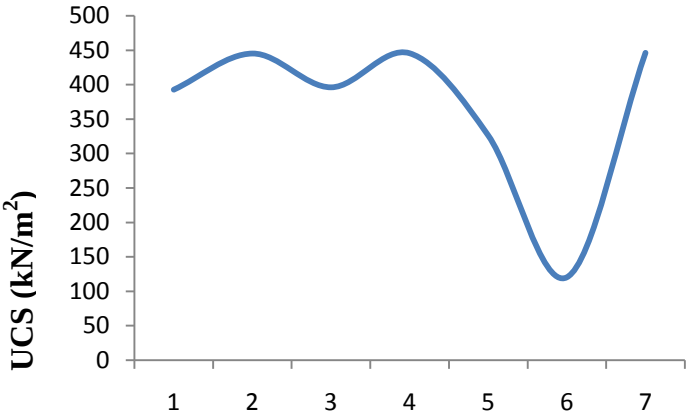


Figure 11: PCSA Content (%)

IV. CONCLUSION

The following conclusions were drawn from the study. The combined percentage of SiO_2, AL_2O_3, Fe_2O_3, MgO and CaO of the Processed Coconut Shell Ash is above 58% which satisfies Samuel Assam minimum requirement value of 58% specified for local stabilizers and as such can be used as a pozzolanic material. The loss in ignition value obtained was less than 7% maximum value required for local stabilizer. It means that, most of the sample were absorbed by the system and the sample contains very little carbon.

The clay sample used in this experimental study contains illite minerals and was classified as A-2-5 using the AASHTO system of classification while the UNIFIED system of classification was CL (showing an inorganic clays of low to medium plasticity, gravelly clays, silty clays). Although at its natural state the soil is not suitable for use as a filled material.

Processed Coconut Shell Ash (PCSA), has reflected a significant increase in natural CBR and UCS values of Ntak – Subgrade, Scheffe's second degree mixture models was developed to determine the mixture proportion ratio and unconfined compressive strength and California Bearing Ratio responses of the soil.

Models developed correspond with experimental results to a reasonable degree of accuracy and could fit and be successfully used in predicting the soil – PCSA properties in the absence of experimental data for soil as they satisfy the significance level of differences with standard statistical requirement.

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