INVESTIGATING THE GEOTECHNICAL PROPERTIES OF KATSI (LOCAL DYE RESIDUE) STABILIZED LATRITIC SOIL

A.B. Shehu[1]*, M. Gomina[2], A.S. Kofarbai, [3] I.Z. Ishaq[4]

[123] Research Officers, Nigerian Building and Road Research Institute, Kano, Nigeria
[4]MSc student, Civil engineering Mewar University Chittorgarh, Rajasthan INDIA.

**Email: abshehudawaki1@gmail.com*

Abstract

This study investigates the impact of katsi as a stabilizer on the performance of lateritic soil. The research findings revealed that the addition of katsi significantly alters the soil's properties. Specifically, the liquid limit, shrinkage limit, and plasticity of the soil decrease with an increase in katsi content, while the plastic limit and California Bearing Ratio (CBR) increase. The Maximum Dry Density (MDD) of the lateritic soil increased from 2.07 to 2.08 g/cm³ with up to 5% katsi addition but showed a decline beyond this percentage. The Optimum Moisture Content (OMC) and CBR also improved with higher katsi content. It is recommended that up to 5% katsi is sufficient for effective soil stabilization. Further research is suggested to explore the effects of katsi on the unconfined compressive strength, shear strength, and permeability of lateritic soil.

KEYWORDS: *Katsi (Local Dye Residue), Stabilization, Lateritic Soil*

1.0 INTRODUCTION

Solid waste management has recently dominated the environmental scene in developing countries, everyday nearly three thousand tons of solid waste is generated in each state thereby causing environmental degradation (Abdulrahman *et al*, 2016). The management of solid waste is cumbersome as many sources of the solid waste exist. Some common sources of solid waste include waste from educational sectors, agricultural sector, industries, etc. In areas where local dying of clothes, skin, etc are carried out, “Katsi” are the major waste product.

The term “Katsi” is the Hausa name used in referring to the by-product residue of indigo dyeing process which is predominately carried out in Hausa land. As the dye loses its effectiveness, a dense deposit known in Hausa language as “dagwalo” is formed at the bottom of the dye pit, this ‘dagwalo’ is left to stand in the pit for about two days and then the whole solution is removed from the pit leaving behind a dense deposit at the base. The deposit is scrapped and removed from the pit and left to dry out completely. It is further burnt with open fire until a light grey ash is formed; this is pounded into powdered ash which is called Katsi or dye residue. According to Ella (2004), about 2 to 3 head pans (46 to 69kg) of Katsi are produced from a dye pit in a circle of dying process with an average annual production of about 112 tons. Hence, it is on this bases, the research seek to address the effect of this solid waste (Katsi) pollution by utilizing it as stabilizing agent in soil.

Soil properties have been improved through the historical backdrop of human civilization. With the present high demand of more sustainable structures, soil improvement procedures have turned into an essential task in the geotechnical engineering projects. Such strategies have been produced as per progresses in current innovation and human resources that make numerous structural building projects more practical (Zubairu ,Ibrahim, and Kabir, 2018). Currently, different methods are used to enhance soil properties mechanically by compaction or by adding different types of materials that improve the characteristics of soils. Some of these materials that are being used as additives change the chemical composition of soils such as cement and lime as. Other reinforcing materials are nonreactive such as fibers, geotextiles, and geogrids (Osinubi, 1998).

Soil reinforcement enhances the bearing capacity of the soil by compaction, proportioning and/or adding a suitable admixture. Reinforcing the subgrade soil which is the most vulnerable layer in the pavement structure improves its performance against various defects. If soil enhancement gained such importance, recycling of plastics also is considered as one of the critical issues which has visibly aided in diverse parts of the life.

2. MATERIAL AND EXPERIMENTATION METHODS

2.1 Materials

2.1.1 Lateritic soil

The international society for soil mechanics and foundation Engineering (ISSMFE) Progress Report (1982/85) states that "a soil can be considered lateritic if it belong to horizon A or B of well drained profiles developed under buried tropical climates, its clay fraction are constituted essentially of the kaolmite group and of iron or aluminum hydrated oxides. These components are assembled in peculiar porous and highly stable aggregate structure". Lateritic soil is a category of residual soil formed from the weathering of igneous rock under conditions of high temperature and high rainfall such as those typically occurring in tropical regions. Laterites are mostly reddish in colour, but not all reddish tropical soils are lateritic. The soil for this research was collected a burrow pit from deposit in Kano State.

2.1.2 Katsi

Katsi was collected from waste deposit in Kofar Mata where dying is extensively carried out. The waste was dried and burnt to about 700 ^oC in an incinerator to form a light grey ash. The Ash is pounded into powdered ash which is called Katsi or dye residue and sieved using sieve #200 (75µm mesh size).

2.2 Material Preparation

The lateritic soils were stabilized with Katsi at concentration levels of 0, 2.5, 5.0, 7.5 and 10 % respectively of weight of soil. The stabilized soil were used to conduct The laboratory tests conducted includes; particle size distribution (sieve analysis), Atterberg limit test, compaction test, and California bearing ratio test.

2.3 Experimentation Method

2.3.1 Particle size distribution

This test aimed at determining the particle size distribution of a soil sample. The specific surface depends on the size and shape of particles. The result of the grain size analysis are widely used for soil classification, design and construction of filters and earth fill dam, highway embankments and determining the suitability of soil for road construction etc. The particle size distribution of the sample was determined using the methods specified in BS 1377 (1990) Part ii for cohesive soil. Wash sieving of the coarse fraction and sedimentation analysis for fine particles were conducted. The soil was first washed through 63µm sieve and the material retained is oven dried and sieved through a series of sieves. Because the percentage passing 63µm BS sieves was more than 10%, a hydrometer analysis was conducted to determine the particle size of silt and clay as recommended in BS1377 (1990).

2.3.2 Atterberg limit tests

The basic behaviour of soil can be determined through the Atterberg limits (liquid limit wl, plastic limit wp, linear shrinkage and plasticity index PI). These are water contents at which the behaviour of soil changes. Extensive correlations are frequently used in estimating the engineering properties from these limits. The Plasticity index is computed as the difference between the liquid limit and plastic limit. An air dried soil sample of 300 g passing 0.425 mm sieve size was taken, missed uniformly with Katsi at 0, 2.5, 5.0, 7.5 and 10.0 % by weight of soil as shown in Table 2.1 were used to conduct the liquid limit, plastic limit and linear shrinkage tests.

Table 2.1: Material Proportion for Atterberg Limit Test

Katsi (%)	Soil (g)	Katsi (g)
0	300	0
2.5	300	7.5
5.0	300	15
7.5	300	22.5
10.0	300	30

A. Liquid limit test: The test was conducted using Cone penetrometer test in accordance with BS 1377(1990) test on the natural soil and stabilized soil samples. The soil paste was then placed in the cup and brought under the plunger of the cone. The plunger was lowered just above the cup and freely released to penetrate in to the soil sample in the cup and waited for 5 seconds, after which the rate of penetration of the plunger was recorded and a sample of the soil was taken for moisture content determination. These steps were repeated for another 3 times each time small amount of water being added. A graph of penetration against moisture content was plotted and liquid limit was obtained as the moisture content corresponding to 20 mm penetration.

B. Plastic limit test: The Proportion of the material passing 0.425 mm sieve was used for the determination of plastic limit (Wl). A sample of the wet soil is taken and moulded between the palms of the two hands. The sample was rolled and sub-divided into two sub samples which are further subdivided into parts. The rate of rolling is between 80 and 90 strokes per minute as specified in BS 1377 (1990), counting a stroke as one complete motion of the hand forward and back to the starting position again. The rolling was done until the threads are of about 3 mm diameter as specified in BS 1377 (1990). The soil is kneaded together to a uniform mass and rolled again. This process of alternate rolling and kneading was repeated until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread. The pieces of crumbled soil thread are collected and the moisture content was determined and recorded as the plastic limit.

C. Plasticity Index: Plasticity index is the difference between the liquid limit and the plastic limit and indicated the range of moisture content over which the soil remains in a plastic condition. The Plasticity index was computed using Equation 1.

$$\text{Plasticity Index} = \text{Liquid limit } (Wl) - \text{Plastic limit } (Wp) \quad \ldots \quad (1)$$

D. Linear Shrinkage Test: This is the percentage decrease in the length of a bar of mould of standard length in an oven from the liquid limit. It is a good indicator of the activity of a soil. The test was conducted on the natural and the stabilized soil sample in accordance with procedure outlined in BS 1377 (1990).

2.3.3 Compaction test

The compaction test was conducted to determine the relationship between dry density and water content. Factors that influence the degree of compaction are the moisture content, soil type and the compactive effort/energy. British Standard Light (BSL) was used in this study. The soil was compacted in a mould that has a volume of 1000 cm^3. The diameter of the mould is 101.6 mm, during the laboratory test a base plate was placed at the bottom of the mould and an extension at the top. The soil (see Table 2.2) was mixed with varying amount of water and then compacted in three layers by a rammer that delivers twenty seven (27) blows to each layer. The rammer weighs 2.5 kg and has a drop of 450 mm. For each of the compacted samples, protruding soils are carefully levelled off with a knife or spatula. The soil sample was then removed from the mould and a little portion taken for moisture content determination. For each percentage of water added to the soil samples. The dry density was plotted against the moisture content and the maximum point on the resultant curve gives the Maximum Dry Density (MDD) on the ordinate and Optimum Moisture Content (OMC) on the abscissa. The densities were obtained using Equation 2 and 3.

$$\text{Bulk density } (\rho_b) = \frac{W}{V} \quad \ldots \quad (2)$$

Where,

W = weight of compacted soil V = weight of Mould.

$$\text{Dry density } (\rho_d) = \frac{\rho b}{1+MC} \quad \ldots \quad (3)$$

Where,

MC = moisture content.

Table 2.2: Material Proportion for Compaction Test

Katsi (%)	Soil (g)	Katsi (g)
0	3000	0
2.5	3000	75
5.0	3000	150
7.5	3000	225
10.0	3000	300

2.3.4 California Bearing Ratio (CBR)

The CBR test was conducted in accordance with BS1377: Part 4: (1990). The aim of the CBR test is to determine the relationship between force and penetration. For the standard compaction, about 6 kg of the pulverized soil sample was mixed with the required Katsi content blend at OMC as shown in Table 2.3. The mixture was then compacted in 5 layers in the CBR mould, 62 blows of the 4.5 kg rammer was applied to each layer. The extension collar was removed and the top of the compacted sample trimmed carefully and waxed. In testing the specimens, the mould containing the compacted soil with the base plate in place were positioned on the lower plate of the machine, the plunger was then made to penetrate the specimen until it failed. The mould was then inverted, base plate removed and the procedure repeated for the base of the specimen. The value of the force at each 0.25 mm interval was recorded until failure of the specimen. From the values of penetration and force recorded, a curve of force against penetration was thus obtained. Correction was made where the curve concave upward by drawing a tangent in all cases, the point where the tangent cuts the penetration axis serve as the new origin. The CBR value was calculated at 2.5 mm and 5.0 mm penetration, the greater of the two values was taken as the CBR of the soil for the blend in question. However, where the values were within 1.0 % of each other, the mean value of the two readings was considered, otherwise the higher value was recorded as the CBR of the specimen. The standard load for 2.5 mm and 5.0 mm are 13.24 kN and 19.96 kN respectively.

Table 2.3: Material Proportion for Compaction Test

Katsi (%)	Soil (g)	Katsi (g)	OMC (%)
0	6000	0	OMC at 0 % Katsi
2.5	6000	150	OMC at 2.5 % Katsi
5.0	6000	300	OMC at 5.0 % Katsi
7.5	6000	450	OMC at 7.5 % Katsi
10.0	6000	600	OMC at 10.0 % Katsi

3 RESULTS AND DISCUSSION

The summary results of tests (particle size distribution, atterberg limit test, compaction test, and California bearing ratio) conducted in this study are reported in the subsequent section.

3.1 Particle Size Distribution

The particle size distribution obtained using the sieve analysis (dry sieving) and hydrometer analysis methods are presented in Figure 1. The soil is low plastic soil with 43.72 % passing 200 µm sieve. This value is more than the recommended limit (≤ 35 %) provided by FMWH (2012). Hence, the soil could be considered not suitable material for sub-base and base course in highway. In addition, the soil was classified as Clayey sand and A-6 (2) using USCS and AASHTO classification respectively.

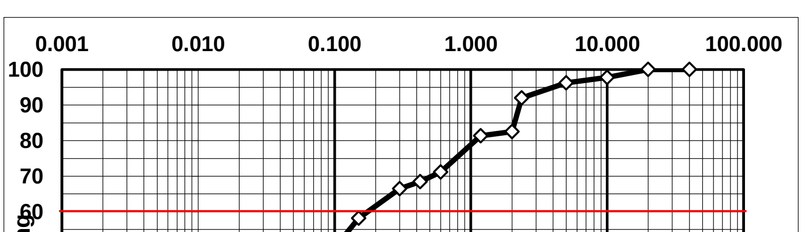

Figure 1: Particle Size Distribution Curve of Lateritic Soil

3.2 The Effects of Katsi on the Consistency of Lateritic Soil

The effects of katsi on the consistency of lateritic soil were assessed using liquid limit, plastic limit, plasticity index and shrinkage limit as presented in Figure 2.

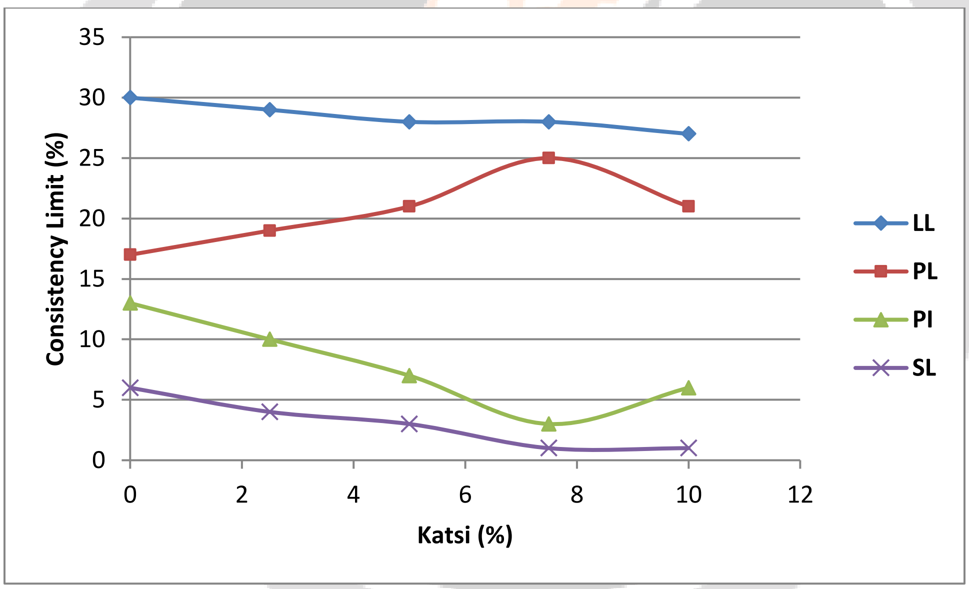

Figure 2: Consistency of Lateritic Soil

Where;

LL = Liquid limit PL = Plastic limit PI = Plasticity index SL = Shrinkage limit

The liquid limit of the soil generally decreases with increase in katsi content as shown in Figure 2. The liquid limits change could be due to the cation exchange reaction and occulation-aggregation of soil particles. The decreases in liquid limits of stabilized soil are 30, 29, 28, 28 and 27 % respectively for increasing katsi content in the order 0, 2.5, 5.0, 7.5 and 10 % in the soil. The gradual reduction of the liquid limit is evident for improvement of the soil. In addition, the liquid limit for the range of katsi content (0 – 10 %) satisfies the requirement of the FMWH (2012).

The plastic limit of the soil increases with addition of katsi as shown in Figure 2 from 17 to 21 %. An increase in plastic limit results from aggregation and cementation of particles into larger size clusters. Another possible reason is the water trapped within intra-aggregate pores. The presence of intra-aggregate water increases apparent water content without really affecting the interaction between aggregates (*Gruber et al*, 2001). In addition, the increase in plastic limit could be attributed to the presence of presence of CaO which has being documented by different studies to be

significantly responsible for the increase in plastic limit as a result of cation ion exchange of Ca^{2+} in the soil mixture (Adeyanju and Okeke, 2019).
The plasticity index of the soil generally decreases with increase in katsi content as shown in Figure 2. The high percentage of CaO, has being documented by different studies to be significantly responsible for the improvement in plasticity index as a result of cation ion exchange of Ca^{2+} in the soil mixture. This reduces the affinity of the soil to water, as the soil minerals are modified (Adeyanju and Okeke, 2019). A reduction of the PI from 13 to 6 % was observed for the katsi stabilized soil.
As shown in Figure 2, increase in katsi content decreases the shrinkage of the soil. The decrease in shrinkage with addition of katsi could be attributed to reduction of plasticity index. In addition, the decrease could also be attributed to the increased physico-chemical reaction or ion exchange between katsi and soil.

3.3 The Effects of Katsi on the Compaction of Lateritic Soil

The effect of katsi on the maximum dry density (MDD) of lateritic soil is presented in Figure 3. The figure shows that katsi increases the MDD from 2.07 to 2.08 g/cm^3 at 0 to 5.0 % addition respectively and reduces beyond 5.0 % addition of katsi to 1.83 g/cm^3 at 10 %. The increase in MDD could be attributed to filler property of the fine particle of katsi. The decrease could be attributed to the effect of lower density katsi displacing a more dense soil.
The effect of katsi on the optimum moisture content (OMC) of lateritic soil is presented in Figure 4. The figure shows that the OMC from 11.2 to 15.39 % at 0 to 10.0 % addition respectively of katsi. The increase in OMC could be attributed to high content of CaO in katsi. The increments in OMC with increase in katsi could be attributed to the increased amount of water required in the system to adequately lubricate all the particles in the soil-katsi mixture. It could also be as a result of increasing surface area due to excess fine particle of katsi, thereby making the mixture to require more water for hydration process.

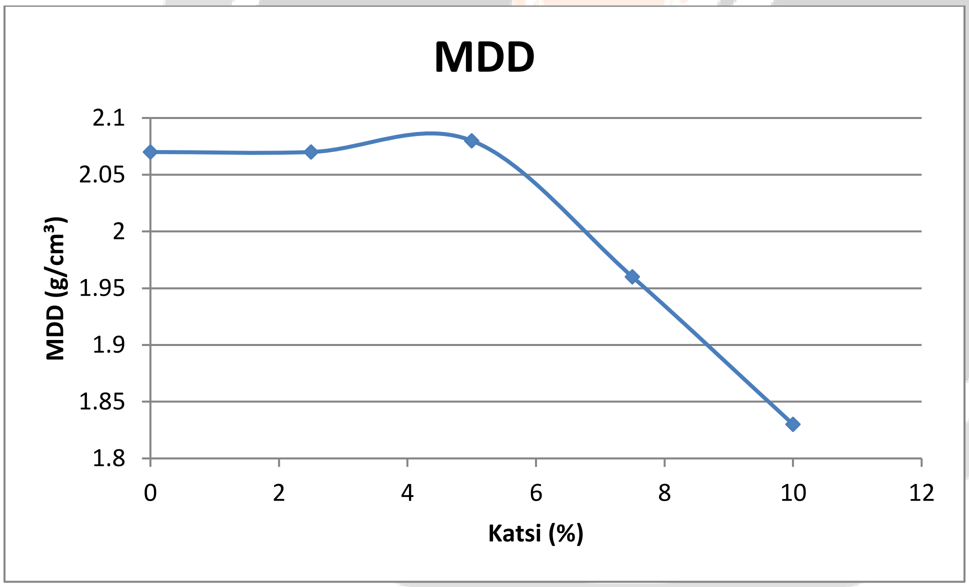

Figure 3: Maximum Dry Density of Katsi – Stabilized Lateritic Soil

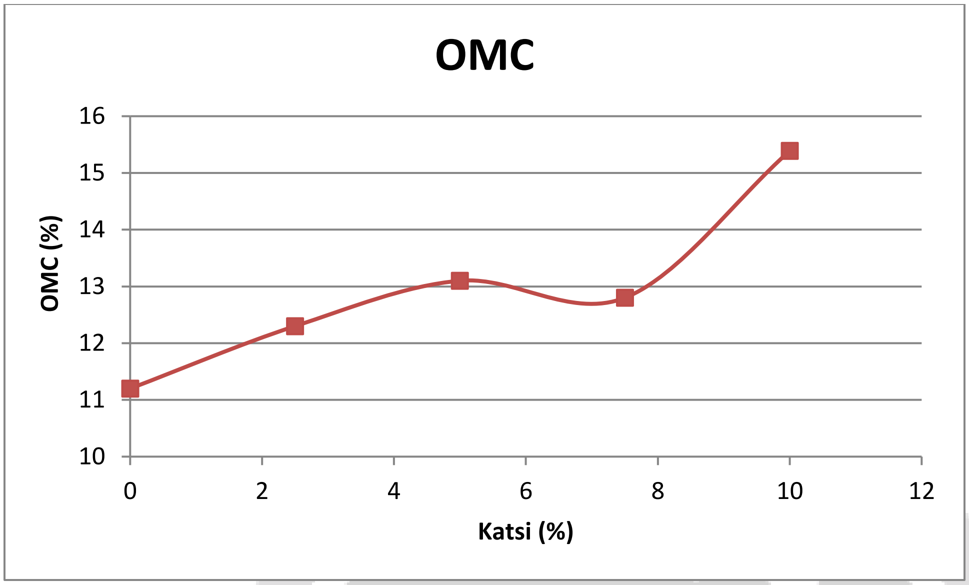

Figure 4: Optimum Moisture Content of Katsi – Stabilized Lateritic Soil

3.4 Effects of Katsi on the California Bearing Ratio of Lateritic Soil

The variation of California bearing ratio (CBR) of katsi Stabilized Soil is presented in Figure 5. It was observed from the figure that CBR values recorded an increase as katsi content increase. The observed increase in the CBR was due to the formation of a crystalline phase of CSH, which contributes to strength gain. The present of katsi has increased the CBR value from 18 to 73 %. These values are greater than the 15 % minimum CBR value required for pavement subgrades (Nigerian General Specifications, 1997). However, at 5 % and beyond, the CBR values were more than 30 % as specified by the Federal Ministry of Works (2012). This implies that the soil could be useful sub-base and base material when stabilized with not less than 5 % katsi content. The increase in CBR value of the soil with addition of katsi is an indication of improvement of the strength properties of the soil.

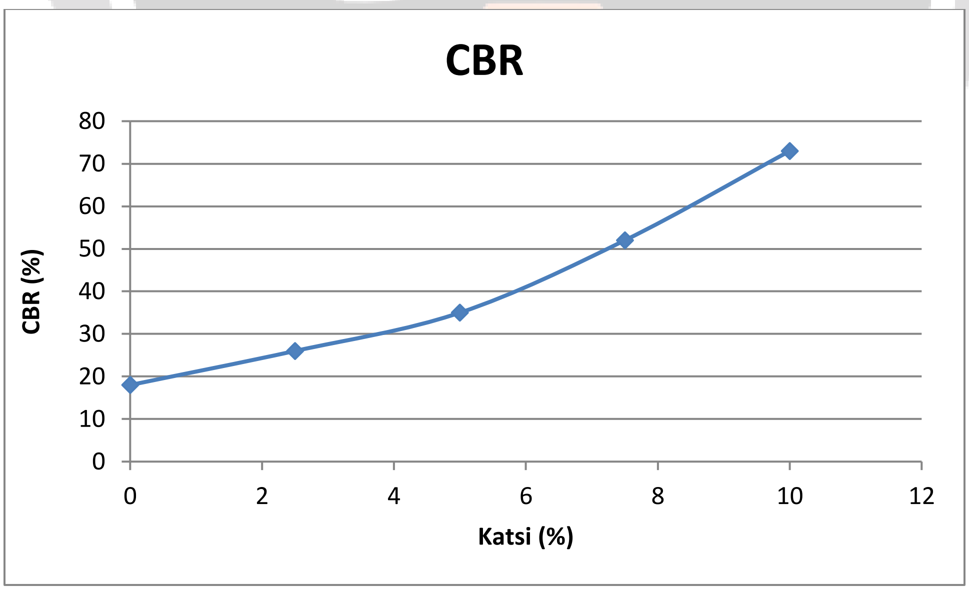

Figure 5: California Bearing Ratio of Katsi – Stabilized Lateritic Soil

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Base on the findings of the research on the performance katsi on lateritic, the following deductions were reached;

1. The liquid limit, shrinkage limit and Plasticity of the soil generally decreases with increase in katsi content.
2. The plastic limit and CBR of the soil generally increases with increase in katsi content.
3. The MDD of the lateritic soil increases with increases the MDD from 2.07 to 2.08 g/cm^3 at 0 to 5.0 % addition respectively but decreases beyond 5 % katsi content.
4. The OMC and CBR of the lateritic soil increases with increasing katsi content.

4.2 Recommendations

Base on the above deductions of this the study, the following suggestions were made:

1. For an effective performance of katsi as soil stabilizer, up to 5 % each is adequate for stabilization.
2. Further study should be conducted on the effect of katsi on Unconfirmed compressive strength, shear strength and permeability

REFERENCES

AASHTO (1986). Standard Specification for Transportation Materials and Methods of Sampling and Testing 14th ed. *American Assoc. of States Highway and Transportation officials.*

Abdulrahman, H., Suleiman, A and Idi, M. A. (2016). Comparative Use of Cement and Katsi to Stabilize Laterite as a Liner in Containment Facility. International Journal of Scientific & Engineering Research, Volume 7, Issue 12, pp. 473 – 479.

Adam, E.A. and Agip, A.R.A. (2001). *Compressed Stabilized Block Manufacture In Sudan*.United Nations Education Scientific and Cultural Organization, pp 4-27.

Ajayi, L.A. (1985). *The laterite and Laterite Soils in Nigeria.Geotechnical Practice in Nigeria.* Geotechnical Association Publication, Lagos, Nigeria.

ASTM (2006). Standards Practice for classification of soils for engineering purposes (Unified soil Classification system). Designation: D24287. West Conshohocken, United State.

Bashir I.U (2012), *Evaluating the Chemical Properties of Pakia Biglobosa (makuba) as soil stabilizer.* Unpublished Post Graduate Project, Department of Building, A.B.U, Zaria. Pp 11-12.

BS1377 (1990). British Standard Methods of Test for Soils for Civil Engineering Purposes, *British Standards Institution, London.*

BSI (1990). Methods of Test for soils for civil Engineering Purposes (BS 1377: Part 1-9). British standards institution, London.
Ella, O. B. (2001), katsi as a pozzolana in mortar and concrete. , Ph. D. Thesis, Department of Civil Engineering Ahmadu Bello University, Zaria, Nigeria.

Ella O.B, (2004) The use of Katsi (Dye residue) as a pozzolana for partial replacement of cement and concrete, PhD. Thesis submitted to the Dept. of civil engineering A.B.U Zaria

Federal Ministry of Works and Housing (2012) General Specifications for Roads and Bridges, Federal Highway Department (FMWH), Lagos, Nigeria

Haruna, I. (2017). Compressive Strength of Concrete Incorporating Rice Husk Ash and Local Dye Residue (Katsi) as Partial Replacement of Cement. Unpublished B. Eng. Final Year Project, A. T. B. U., Bauchi-Nigeria.

Khalil I.M (2005). *Soil Stabilization with Cassava Starch*, M.Sc Thesis, Department of Building, Faculty of Environmental Science, University of Jos, Nigeria.

Osinubi K.J. (1998): "Influence of compaction delay on properties of cement stabilized lateritic soil" Nigerian Journal of Engrg., 6(1), 13-25.

Osinubi, K. J. (1998) "Stabilization of tropical black clay with cement and pulverized coal bottom ash admixture." In: Advances in Unsaturated Geotechnics. Edited by Charles, D., Shackelford, Sandra L. Houston and Nien-Yin Cheng. ASCE Geotechnical Special Publication, No 99, pp 289-302.

Tawfiq, M. (2004). Retrieved from *SoilMechanics.*http//www.eng.fsu.edu/Tawfiq/ soilmech/lecture.html.

Zubairu I.,Ibrahim, H., and Kabir, N. (2018), Investigation Into The Use Of Rice Husk Ash And Local Dye Residue (Katsi) As Partial Replacement For Cement *Globalscientificjournal Volume 6, Issue 6, June 2018, Online: ISSN 2320-9186 www.globalscientificjournal.com*