EVALUATION OF CLAY LATERITE BLOCK IN BUILDING CONSTRUCTION IN KEFFI LOCAL GOVERNMENT AREA OF NASARAWA STATE

BY

JAMES, Sunday Orinya
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DEPARTMENT OF INDUSTRIAL AND TECHNOLOGY EDUCATION
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

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A PROJECT SUBMITTED TO THE SCHOOL OF SCEINCE AND TECHNOLOGY EDUCATION, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQIUREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF TECHNOLOGY (M.Tech) IN INDUSTRIAL AND TECHNOLOGY EDUCATION (BUILDING TECHNOLOGY)

MARCH, 2023

DECLARATION

I hereby declared that this thesis titled "**Evaluation of Clay Laterite Block in Building Construction in Keffi Local Government Area of Nasarawa State**" is a collection of my original research work and it has never been presented for any other sources (Published and Unpublished) has been duly acknowledged.

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SIGNATURE AND DATE

CERTIFICATION

The thesis titled ""**Evaluation of Clay Laterite Block in Building Construction in Keffi Local Government Area of Nasarawa State**" by JAMES, Sunday Orinya, 2016/1//63768TI meets the regulation governing the award of the Degree of Masters of Technology in Industrial and Technology Education (Building Technology) of Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literacy presentation.

Dr. A. M. Hassan ----------
Supervisor Signature & Date

Dr. T. M. Saba ----------
Head of Department Signature & Date
Industrial and Technology Education

---------- ----------
External Examiner Signature & Date

DEDICATION

This work is dedicated to my mother, who inculcated hard working in me, Her disciplinary life has been my source of inspiration and strength throughout this program.

ACKNOWLEDGEMENTS

The researcher's gratitude goes to the Immutable God for His faithfulness. The researcher appreciate his supervisors Dr. A. M. Hassan for their time to read, correct and contribute toward the success of this work. The researcher acknowledges the academic and non-academic staff of the Department of Industrial Technology Education and for their immense contributions toward success of the work.

The researcher also appreciate his friends and colleague for their support during the study. The researcher acknowledged Mr Talba of Adirab Education Consult for his guide and contribution to the success of the project work.

ABSTRACT

This study is designed to Evaluation of Clay Laterite Block in Building Construction in Keffi Local Govt Area of Nasarawa State. Experimental research design was adopted for the study. The study was carried out in High Court, Dadin Kowa and Area Commander locations in Keffi LGA, Nasarawa State Nigeria. Keffi is a town in Nasarawa State, Nigeria. The samples were obtained with the aid of a locally made mold of 50 x 50mm cube size. The mold was constructed to correspond to the shape and size of the samples to be made. A hydraulic press was used to press the material firmly so that the resulting sample could take the shape of the mold. The samples prepared were to be mechanically tested to obtain their compressive strengths. The result indicates that the compressive strength of the samples improves optimally at 9% hydrated lime stabilization and 5% bone ash stabilization for samples cured using the air-dried method of curing for 28days. It is concluded that the use of 9% by weight of the hydrated lime addictive and 5% by weight of bone ash addictive were the optimum amount for the stabilization of laterite soil. The outcome of this research indicates positive results due to the potential of hydrated lime and bone ash to strengthen the laterite. It also shows that bone ash is a sustainable alternative for hydrated lime in stabilization of laterite material. The property of laterite can be enhanced by suitable water proofing treatments and studies on how to achieve this are to be carried out in future research.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Laterite soils as sustainable building materials are described as materials that meet the needs of the present generation without compromising the ability of future generations to meet their own needs adequately. They are environmentally friendly materials. The high cost of construction projects led to a call for the incorporation of laterite in the past and recent projects. Buildings constructed of earth materials are the most common affordable accommodation since earth materials are readily available almost anywhere on the planet. Laterite is a group of highly weathered soils formed by the concentration of hydrated oxides of iron and aluminum (Thagesen, 1996).

Other definitions have used the ratio of silica (SiO_2) and sesquioxides ($Fe_2O_3 + Al_2O_3$) where the ratios are less than 1.33 in lateritic soil. Laterite has been the most widely known and used construction material in building and road construction. In tropical parts of the world, lateritic soils are used as a road making material and they form the subgrade of most tropical roads. They are used as sub-base and bases for low-cost roads and these carry low to medium traffic. Furthermore, in rural areas of Nigeria, they are used as building material for molding of blocks and plastering (Onyelowe, 2016).

Stabilization of soil is the process of changing one or more soil properties through mechanical or chemical means, to produce soil with improved and desired engineering properties. According to the American Society for Testing and Materials (ASTM), the main purpose of soil stabilization includes increasing the strength of an existing soil to enhance its load bearing capacity,

permeability improvement and enhancement of soil resistance to the process of weathering and traffic usage among others (ASTM, 2014). Soil stabilization achieves a number of objectives that are important in obtaining a long-lasting structure from locally available earth materials, including better mechanical characteristics; better cohesion between particles which reduces the porosity and changes in volume due to moisture fluctuations; and improved resistance to rain, wind, and erosion. Soil stabilization techniques include mechanical, physical and chemical stabilization. The choice of building materials in the society has been influenced by availability and cost (Sergio, 2008).

As a result of the high cost of construction materials in most developing countries, owning a house is relatively difficult. In order to solve this problem, it is necessary to explore new ways of producing building materials from locally available materials at low cost. Laterite soil consists of high plastic clay, the plasticity of soil may cause cracks and damage on building foundations, pavement, highway or any other construction projects. It is therefore important, to understand the behavior of laterite soil and thus figure out the method of soil stabilization. In this research, hydrated lime and bone ash were used as the stabilizing agents for the laterite. The major chemical constituent of the lime is calcium hydroxides [Ca (OH) 2] and that of bone ash is calcium oxide/calcium phosphate. Therefore, the aim of this research is to study the behavior of hydrated lime and bone ash treated lateritic soil in comparison with untreated laterite soil.

1.2 Statement of the Problem

The need for sustainable and affordable construction projects in Nigerian and other developing countries is on the rise because of the issue of high cost of cement and other conventional building materials. The use of local materials is of paramount importance to sustainable construction because of its availability, cost effectiveness and ability to protect the environment. Laterite as a

locally available material looks promising as a better alternative to conventional building materials except for a few problems. Laterite soil consists of high plastic clay; the plasticity of laterite may result in cracks and damage on building foundations, pavement, highway or any other construction projects, thus the need for the stabilization of laterite. Environmental pollution is a serious threat to the sustainability of the human race. In Nigerian meat markets and abattoirs, bones are littered everywhere causing a nuisance to human activity. Hence the reason for using bones ash for the stabilization of laterite materials in this study.

1.3 Purpose of the Study

The purpose of this study is to evaluation of clay laterite block in building construction in Keffi Local Govt Area of Nasarawa State. The objectives are as follows:

1. To determine an appropriate mix proportion of stabilized laterite soil using hydrated lime and bone ash as stabilization agents.
2. To study the effect of hydrated lime and bone ash on the compressive strength of laterite.
3. To determine the effect of different methods of curing on the compressive strength of laterite.

1.4 Significance of the Study

Stabilization of laterite prevents future problems like swelling and damping which could lead to failure of the structure built with untreated laterite. It also aids long-lasting of roads and buildings built with laterite thereby saving the cost of maintenance. When laterite is stabilized, it helps to increase the strength and durability of laterite by reducing its porosity. In order to solve the problem of environmental pollution, bone ash was chosen as a substitute for lime to stabilize the

locally available laterite materials. This study has the potential for making affordable homes and sustainable roads from earth materials (laterite) stabilized with cattle bone ash.

1.5 Scope of Work

Laboratory tests that were performed included sieve analysis, Atterberg limits, XRD, FTIR and compression strength. This research is meant to cover the following:

- Identification and characterization of laterite;
- Setting up an experiment to use different levels of the selected stabilization materials (lime and bone ash) to develop stabilized laterite;
- Comparison of the strength of the stabilized soils to the raw sample collected;
- The use of compressive strength to evaluate the effectiveness of the different stabilization agents in improving the quality of laterite in the construction industry;
- Determination of the effect of different methods of curing on both the stabilized laterite and untreated sample collected.

As a result of the differences in lateritic formations and mineral constituents, the results obtained from this research will only be applicable to laterite specimen produced from lateritic soils in three (3) different location Keffi LGA or any other laterite or soil samples with similar characteristics.

1.6 Research Questions

The aim of this research is to study the behavior of lime and bone ash treated laterite soil in comparison with untreated laterite soil. The objectives are as follows:

1. What are the appropriate mix proportion of stabilized laterite soil using hydrated lime and bone ash as stabilization agents.

2. What is the effect of hydrated lime and bone ash on the compressive strength of laterite.
3. What is the effect of different methods of curing on the compressive strength of laterite.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual Framework

2.1.1 Definition and Formation of Laterite

Laterite is a soil and rock type rich in iron and aluminum commonly formed in hot and wet tropical areas. Almost all laterites are of rusty-red coloration because of the high iron oxide content. They are referred to as a soil type as well as being a rock type. Laterites are formed from the leaching of parent sedimentary rocks, metamorphic rocks and igneous rocks which leaves the more insoluble ions of mainly iron and aluminum (Norton, 2000). Relallack (1997) prefers to define a laterite as a rock or part of a soil, not a true soil. The mineralogical and chemical compositions of laterites are dependent on their parent rocks. The mechanism of leaching involves acid dissolving the host mineral lattice, followed by hydrolysis and precipitation of insoluble oxides and sulfates of iron, aluminum and silica under high-temperature conditions (Whittington et al, 2000).

The above processes usually produce yellow, brown, red or purple materials, with red being the predominant color. While tropical weathering in oxidizing conditions generally leads to reddening, this does not necessarily produce a lateritic material–hence the widespread confusion concerning laterite and its behavior. Geology of Nigeria by Kogbe (1975) describes laterites to consist of three layers, a basal lateritic clay, a middle laterite gravel and a surface crust. Hence, types of laterites are as follows:

(i) **Laterite crust:** Laterite crust has a cellular texture and is usually hard to break with a geologists' hammer. Light explosives may be required to excavate this type of laterite.

It is commonly found on top of flat-topped hills or as boulders on slope surfaces and often is encountered while digging building foundations.

(ii) **Laterite gravel:** Laterite gravel may be found below a layer of laterite crust. At some locations, the gravel deposit is only covered by a thin layer of soil. Laterite gravel is usually pisolitic.

(iii) **Laterite Clay:** Laterite clay is often located below the gravel or the crust, and usually above the weathered basement. It has a very rich reddish-brown color, with patches of pinkish white material (probably Kaolinite). Flakes of micas are visible in hand specimens. It often is used in the construction of earth dams.

2.1.2 Occurrence of Laterite

The first global synthesis of the distribution of laterite prepared by Prescott and Pendleton in 1952 is presented in **Figure 2.1** (Pearson, 1970).

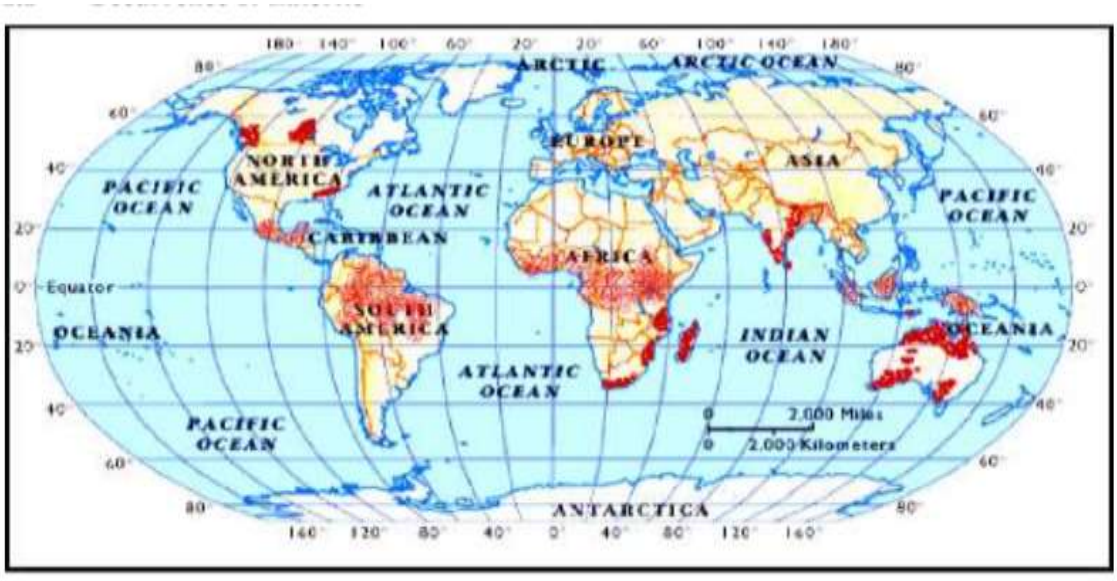

Figure 2.1: Worldwide Distribution of Laterite (Pearson, 1970)

Inconsistency in terminology and information exchange is one of the major challenges to creating an integrated database of worldwide laterite research. Laterite is known by different names in different countries and even in different parts of the same country. Hence, the need to know the names used to describe it in various places. Laterite and associated soils are widely distributed in the tropics and subtropics of Africa, Australia, India, South-East Asia, and South America.

2.1.3 Methods of Soil Stabilization

The process of soil stabilization refers to changing the physical properties of soil in order to improve its strength, durability, or other qualities. Soil that has been stabilized will have a vastly improved weight bearing capacity, and will also be significantly more resistant to being damaged by water, frost, or inclement conditions. Different types of soil stabilization have been used for thousands of years. They include mechanical, chemical, physical and polymer soil stabilization.

2.1.3.1 Chemical Stabilization

Chemical solutions are one of the major types of soil stabilization. One method to improve expansive soils is chemical stabilization. Chemical stabilization includes the use of chemicals and emulsions as compaction aids to soils, as binders and water repellents, and as a means of modifying the behavior of soil (Das, 2003). It involves deep mixing and grouting. Chemical stabilization can aid in dust control on roads and highways, particularly unpaved roads, in water erosion control, and in fixation and leaching control of waste and recycled materials. Portland cement, lime, asphalt, calcium chloride, sodium chloride, and paper mill wastes are common chemical stabilization agents.

The effectiveness of these additives depends on the soil conditions, stabilizer properties, and type of construction (i.e., houses, roads, etc.). The selection of a particular additive depends on costs,

benefits, availability, and practicality of its application. The behavior of each of these admixtures differs vastly from the others; each has its particular use and conversely, each has its own limitations (Gidigasu, 1976). Chemical stabilization can be achieved via various combinations which include the following:

(a)Lime as a Soil Stabilizer

Lime has been used in the past in one form or the other to improve the engineering behavior of clayey soils. As a result of the proven success of lime stabilization in the field of highways and airfield pavements, it is being extended for deep in-situ treatment of laterite/clayey soils to improve their strength and reduce compressibility. The improvements in the properties of soil are attributed to the soil-lime reactions (Clare and Cruchley, 1957; Ormsby and Kinter, 1973; Locat et al. 1990). Hydrated lime is a fine powder, whereas quicklime is a more granular substance. Quicklime is more caustic than hydrated lime, so additional safety procedures are required with this material. The type of the lime used as a stabilizing agent varies from country to country. The most commonly used products are hydrated lime [Ca(OH)2], MgO, calcitic quicklime [CaO], and dolomitic quicklime CaO.MgO.

Lime will primarily react with medium, moderately fine, and fine-grained soils to produce decreased elasticity, increased workability, reduced swell, and increased strength. The addition of lime increases the soil pH, which also increases the cation exchange capacity. Consequently, even calcium-rich soils may respond to lime treatment with a reduction in the soil's plasticity. A reduction in plasticity is usually accompanied by reduced potential for shrinking or swelling. Stabilization occurs when the proper amount of lime is added to reactive soil. When introducing lime into soil for stabilization, Ca2+ is partly adsorbed on the surfaces of clay particles in replacement of monovalent cations such as Na+ and K+. The amount of Ca2+ adsorbed depends

on the cation exchange capacity of the treated soil. In fact, all the adsorbed cations are no longer available for pozzolanic reactions.

The amount of lime required to satisfy the affinity of soil for lime is called the Lime Fixation Point (LFP). The lime in excess of the LFP is involved in the process of cementing. The reactions between the lime, silica and alumina-free, contributing to the formation of new minerals such as CSH (calcium silicate hydrates), CAH (calcium aluminate hydrates) and CASH (alumino-calcium silicate hydrates), are primarily responsible for the consolidation (Lemougna, et al, 2011). Lime is generally restricted to the warm to moderate climates since lime-stabilized soils are susceptible to breaking under freezing and thawing. Lime stabilization will result in the plasticity of the soil and an increase in the soil strength.

(b)Cement as a Soil Stabilizer

The mineralogy and granulometry of cement treated soils have little influence on the reaction since the cement powder contains in itself everything it needs to react and form cementitious products (Lemougna, et al, 2011). The main reaction in a soil/cement mixture result from the hydration of the two anhydrous calcium silicates [3CaO. SiO2 (C3S)] and 2CaO. SiO2 (C2S)], the major constituents of cement, which form two new compounds: calcium hydroxide (hydrated lime called portlandite) and CSH, the main binder of concrete. Cement will create physical links between particles, increasing the soil strength; meanwhile lime needs silica and alumina from clay particles to develop pozzolanic reactions (Kerali, 2001).

Cement stabilization mechanism is mainly controlled by hydrolysis and hydration. Cement stabilization usually results in decreased density, increased compressive strength, decreased

plasticity, decreased volume, and change in characteristics of expansive clays when compared to the natural soil (PCA, 1992).

(c) Bone Ash as a Soil Stabilizer

Bone is a dynamic tissue that performs mechanical, biological, and chemical functions. The main component of bone is hydroxyapatite as well as amorphous forms of calcium phosphate, possibly including carbonate. Bone chemical and physical properties are affected by age, nutrition, hormonal status, and diseases (Loveridge, 1999). Cattle bones are the source of production of bone ash. Bone ash is grey-white powdery ash obtained from the burning (calcination) of bones. It is primarily composed of calcium phosphate. Calcination is known as a process of high-temperature heating in the presence of atmospheric oxygen. The end product being pure bone mineral, a compound related to hydroxyapatite.

All organic materials are combusted to CO2. Bone ash is significant because some of its important properties are due to the unique cellular structure of bones that is preserved through calcination (Ayininuola et al, 2016). Bone ash has excellent nonwetting properties; it is chemically inert, free of organic matters and has very high heat transfer resistance. According to Ayininuola and Shogunro (2013), calcined bone ash contains the following: CaO (45.53%), P2O5 (38.66%), MgO (1.18%), SiO2 (0.09%), Fe2O3 (0.1%), Al2O3 (0.06%) and Moisture (0.11).

2.1.3.2 Mechanical Stabilization

The oldest method of soil stabilization is mechanical stabilization. It has to do with physically changing the property of the soil in order to better the gradation, solidity and other characteristics. Mechanical stabilization is widely used in road construction and requires a prior analysis of the soil to determine the optimum water content for better soil compressibility. Mechanical

stabilization consists of compaction of the soil to affect its resistance, compressibility, permeability and porosity.

2.1.3.3 Physical Stabilization

Physical stabilization refers to changing the properties of soil via texture treatment, heat or electric treatments that result in the drainage of the soil and gives better structural properties to the soil. Physical stabilization may also involve the introduction of synthetic fibers or fibers originating from plants, animals and minerals into the soil. This method is used when there are reasons not to affect the particle size distribution of the soil or if the material is sensitive to movements induced by factors such as water action, thermal expansion, *etc*. These movements can then be countered by a frame made of fibers (Lemougna, et al, 2011).

2.1.4 Engineering Classification of Soil

Classification of different soils with similar properties into groups and sub-groups may be done according to their engineering behaviors/properties. The systems of classification provide brief information to define the general characteristics of soils which are largely varied, without providing detailed descriptions. They are the American Association of State Highway and Transportation Officials (AASHTO) classification system and the Unified Soil Classification System. The AASHTO classification system is used mostly by soil engineers of state and country highway departments. Both systems take into consideration the particle size distribution and Alterberg limits. Geotechnical engineers generally prefer the Unified system of classification.

2.1.4.1 AAS HTO Classification System

The AASHTO system of soil classification was developed in 1929 as the Public Road Administration Classification System. According to this system, soil is classified into seven major

groups: A-l through A-7. Soils classified under groups A-1, A-2, and A-3 are granular materials of which 35% or less of the particles pass through the No. 200 sieve. Soils of which more than 35% pass through the No. 200 sieve are classified into groups A-4, A-5, 4-6, and A-7. These soils are mostly silt and clay-type materials. The classification system is based on the following criteria:

l. Grain size

a. Gravel: Fractions passing the 7-5-mm (3-in.) sieve and retained on the No. l0 sieve

b. Sand: Fractions passing the No. 10 sieve and retained on the No.200 sieve

c. Silt and clay: fraction passing the No. 200 U.S. sieve

2. Plasticity: The term silty is used when the fine fractions of the soil have a plasticity index of 10 or less. The term clayey is used when the fine fractions have a plasticity index of 11 or more.

3. If cobbles and boulders (a size larger than 75 mm) are encountered, they are excluded from the portion of the soil sample from which classification is made. However, the percentage of such material is recorded.

2.1.4.2 Unified Soil Classification System

The original form of the Unified Soil Classification System was proposed by Casagrande in 1942 during World War II for use in airfield construction undertaken by the Army Corps of Engineers. In cooperation with the U.S. Bureau of Reclamation, the Corps revised this system in 1952. At present, it is widely used by engineers (ASTM designation D -2481). In order to use the classification system, the following points must be kept in mind:

1. The classification is based on material passing a 75 mm (3 in.) sieve.

2. Coarse fraction: percent retained above No. 200 sieve = 100–F200 = R200

3. Fine fraction: percent passing No. 200 sieve = F200

4. Gravel fraction: percent retained above No.4 sieve = R4

According to the Unified Soil Classification System, the soils are dvided into two major categories:

l. Coarse-grained soils that are gravelly and sandy in nature with less than 50% passing through the No. 200 sieve. The group symbols start with prefixes of either G or S. G stands for gravel or gravelly soil, and S for sand or sandy soil.

2. Fine-grained soils with 50% or more passing through the No. 200 sieve. The group symbols start with prefixes of M, which stands for inorganic silt, C for inorganic clay, and O for organic silts and clays. The symbol Pt is used for peat, muck, and other highly organic soils. Other symbols used for the classifications are:

W- Well graded

P- Poorly graded

L - Low plasticity (liquid limit less than 50)

H- High plasticity (liquid limit more than 50)

2.2 Review of Empirical Studies

Kasthurba et al. (2014) explored the use of laterite as a sustainable building material in developing countries. Their research work summarizes the occurrence and characteristics of laterite and then highlights the need for developing a universal database of properties and standard testing protocols to facilitate evaluation and extensive use of laterite in building applications.

Azeko (2015) carried out research on recycling of waste PE and using it as reinforcement in laterite bricks for sustainable building materials. He found out that the composite containing 20 vol. % of PE had the best combination of flexural/compressive strength and fracture toughness. The result also indicates that beyond 20 vol. % of PE, the compressive/flexural strengths as well as the fracture toughness values decrease. Due to the potential of geopolymer to fill spaces that exist between soil particles, AB Aziz and Mukri (2016) worked on how to determine the best percentage of geopolymer that is suitable to improve the compaction parameter of laterite soil. Based on the results, it is proved that the laterite soil mix with 15% of geopolymer gives the best value of dry density and moisture content of soil with the heavy and standard compaction effort.

Mustapha (2015) worked on natural fiber (straw) reinforced laterite and the result indicates improved mechanical properties such as compressive strength, flexural strength, and fracture toughness. A new liquid polymer soil stabilizer, which was developed for use as a means of stabilization treatment of soil known as SS299, was examined by Marto, et. al. (2013). The results indicated that SS299 soil stabilizer is able to significantly increase the unconfined compressive strength and shear strength of laterite soil.

The influence of bone ash on the shear strength of soil was investigated by Ayininuola and Shogunro (2013) and they discovered that bone ash played a fascinating role in increasing the shear strength of the soil. The geotechnical properties of laterite soil stabilized with liquid soil stabilizers, canlite (SS 299) was analyzed by Mohd Yunus et al (2015). They found out that the SS 299 soil stabilizer is able to improve the geotechnical properties of the laterite soil. The unconfined compression strength increased with the curing period, the variation mainly occurring in the first 28days.

Achampong et al. (2013) worked on the chemical stabilization of laterite soils for road construction by looking at a case study of the laterite soils at Legon in Ghana. They discovered that only 6% lime addition was the most suitable for stabilizing the soil when the results were compared to the specifications of the Ghana Highway Authority (GHA).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Design of the Study

The study adopted experimental Research design. According to Patrick (2015) experimental Research design is the blue print of procedure which enables the researcher to test hypothesis by reaching valid conclusions about relationship between dependent and independent variables. Experimental research is a scientific approach to research, where one or more independent variables are manipulated and applied to one or more dependent variables to measure their effect on the latter.

A true experiment is a type of experimental design is thought to be the most accurate type of experimental research. A true experiment is also thought to be the only experimental design that can establish cause and effect relationships (Yolanda, 2015).

This research design was adopted for the study to provide experimental evidence for evaluation of clay laterite block in building construction in Keffi Local Govt Area of Nasarawa State

3.2 Area of Study

The study was carried out in High Court, Dadin Kowa and Area Commander locations in Keffi LGA, Nasarawa State Nigeria. Keffi is a town in Nasarawa State, Nigeria. Its headquarters are in the town of Keffi. Keffi is 50 kilometers from Abuja. Nasarawa State university is located in Keffi sitting along Keffi-Akwanga express way. It has an area of 138 km^2 and a population of about 92,664 at the 2006 census.

3.3 Materials and Sample Preparation

Nigerian laterite samples were chosen for this research because they are abundantly available and also used in many geotechnical engineering works in Nigeria. Laterite soil was obtained from a depth of 1–2 m below the ground surface. The two different laterite samples considered for this research work were got from High Court, Dadin Kowa and Area Commander locations in Keffi LGA, Nasarawa State Nigeria. The laterite materials were collected, air dried and ground to fine particles (<80μm). Commercially available hydrated lime and bone ash got from calcined cattle bones were used to stabilize the laterite materials differently. The hydrated lime and the bone ash were passed through No. 40 sieve before usage. The raw laterite sample, hydrated lime, and cattle bone ash are shown below in **Figure 3.1**(**a**), **3.1** (**b**) and **3.1** (**c**) respectively.

Figure 3.1(a) Raw Laterite

Figure 3.1(b) Hydrated Lime Soil Stabilizer

Figure 3.1 (c): Cattle bone ash after calcination and grinding

In this study, the raw laterite and the stabilized laterite were used to mold bricks of different material matrices and compositions as shown in Figure 3.2 The hydrated lime and bone ash were first mixed dry with the laterite respectively. Subsequently, a calculated amount of water needed to satisfy the moisture requirement of the soil and the hydration needs of the stabilizer was added.

The samples were obtained with the aid of a locally made mold of 50 x 50mm cube size. The mold was constructed to correspond to the shape and size of the samples to be made. A hydraulic press was used to press the material firmly so that the resulting sample could take the shape of the mold. The samples prepared were to be mechanically tested to obtain their compressive strengths.

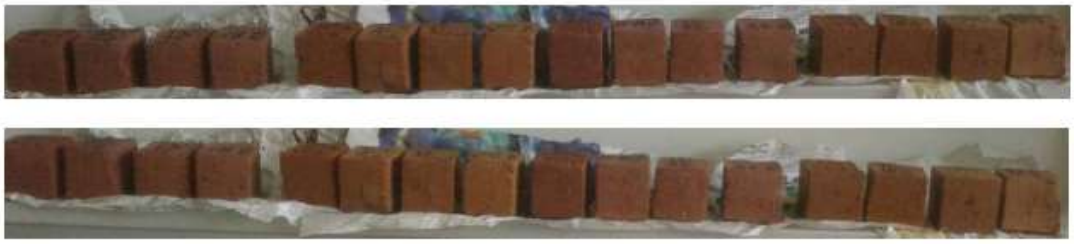

Figure 3.2 Prepared test samples (laterite bricks)

a. Preliminary Laboratory Tests

In order to understand the behavior of the laterite samples used in this research properly, major preliminary tests were taken. The necessary preliminary tests considered included Sieve analysis, Moisture Content Test, and Atterberg Limits Test.

i. Sieve Analysis

A known weight of material, the amount being determined by the largest size of aggregate, was placed upon the top of a group of nested sieves (the top sieve had the largest screen openings and the screen opening sizes decreased with each sieve down to the bottom sieve which had the smallest opening size screen for the type of material specified) and shaken by mechanical means for a period of time. After shaking the material through the nested sieves, the material retained on each of the sieves was weighed. The cumulative method required that each sieve beginning at the top be placed in a previously weighed pan (known as the tare weight), weighed, the next sieve's contents added to the pan, and the total weighed. This was repeated until all sieves and the bottom pan had been added and weighed. A known weight of the sample was also washed and sedimentation analysis was carried out to give a more detailed result for the particle size distribution of the sample.

ii. Water /Moisture Content Test

Percentage moisture content was determined as described in ASTM D 2216 - Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil Aggregate Mixtures. This test was performed to determine the percentage quantity of moisture present in the laterite sample. For many soils, the water content may be an extremely important index used for establishing the relationship between the way a soil behaves and its properties. The consistency of a fine-grained soil largely depends on its water content. The water content is also used in expressing the phase relationships of air, water, and solids in a given volume of soil.

To do the moisture content test, the moisture can and lid number were recorded. The mass of empty, clean, and dry moisture can with its lid (MC) was determined and recorded. The moist soil was placed in the moisture can and the lid secured. The mass of the moisture can (now containing the moist soil) with the lid (MCMS) was determined and recorded. The lid was removed and the moisture can (containing the moist soil) was placed in the drying oven that was set at 105 °C. The oven was left overnight after which the moisture can was removed from the oven. The lid on the moisture can using gloves was carefully but securely replaced, and was allowed to cool to room temperature. The mass of the moisture can and lid (containing the dry soil) (MCDS) was determined and recorded. The water/moisture content of the laterite was then calculated.

iii. Atterberg Limits Test

The Atterberg Limits Test was performed to determine the plastic and liquid limits of a fine-grained soil. The test was conducted as explained in ASTM D 4318 - Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils. The Atterberg limits are based on the moisture content of the soil. The PL is the water content, in percent, at which a soil can no longer

be deformed by rolling into 3.2 mm (1/8 in.) diameter threads without crumbling. The liquid limit (LI) is the moisture content that defines where the soil changes from a plastic to a viscous fluid state.

The shrinkage limit is the moisture content that defines where the soil volume will not reduce further if the moisture content is reduced. The Plasticity index (PI) is the measure of the measure of the plasticity of a soil. It is the size of the range of water contents at which the soil exhibits plastic properties. Soil descriptions based on PI include: Nonplastic (PI=0), slightly plastic (PI <7), medium plastic (7-17) and highly plastic (>17). Soils with a high PI tend to be clay, those with a lower PI tend to be silt and those with a PI of zero (non-plastic) tend to have little or no silt/clay. Various soil engineering properties have been correlated to the liquid and plastic limits, and these Atterberg limits are also used to classify a fine-grained soil according to the Unified Soil Classification System or AASHTO system.

3.4 Experimental Design

Various tests including compressive strength, XRD, and FTIR tests were designed to measure the compositions of the samples used and to ascertain the effectiveness of the hydrated lime and bone ash stabilizers on laterite samples.

3.4.1 Compressive strength test

The molded samples were cured for 28days after which the compressive strengths were measured with a Universal Mechanical Testing Machine (TIRA test model 2810, Thuringia, Germany) as shown in **Figure 3.3**. The compressive strength tests were done under displacement control at a displacement rate of 0.02 mm/s. The specimens were weighed with weighing balance and then, loaded monotonically until failure occurred by breaking into two or more pieces. The actual

dimensions of the specimens were measured using a pair of Vernier calipers before testing with the Universal machine. The specimens were deformed monotonically to failure at a loading rate of 24 kN/s. The compressive strengths (σc) were calculated from:

$\sigma c = \frac{Fq}{Ao}$; where Fq is the force at the onset of failure and Ao is the initial cross-sectional area.

The effectiveness of the stabilizers was tested by treating laterite samples with different percentages of different stabilizers (hydrated lime and bone ash) and using compressive strength tests to evaluate their resulting strength. Also, different methods of curing were employed in the curing of the molded laterite bricks before crushing the samples to ascertain their compressive strengths. The curing methods used include: oven dried, air dried and sun-dried methods of curing.

Figure 3.3: Experimental Set-up for Compressive Strength Test

3.4.2 XRD test

The mineralogical compositions of the laterite samples used for this research were analyzed using XRD test. The test was carried out by Rigaku Miniflex 600 XRD machine with range 10-70 at a rate of 2 degrees/min and Cu K radiation as shown in Figure 3.4 below.

Figure 3.4: XRD Machine

3.4.3 FTIR test

The FTIR test was used in the characterization of the bone ash used in this research. The test was done using the Nicolet is5 Thermo Scientific FTIR spectrometer as shown in **Figure 3.5** below.

Figure 3.5: FTIR sp

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Structure and Composition of Samples

The composition of the two samples were presented by mineralogical analysis using XRD and confirmed by a compressive strength test using the Universal Testing machine. The reddish sample from Dadin Kowa is identified as Laterite sample 1 (LS1) whereas the reddish-brown sample got from High Court Area is identified as Laterite sample 2 (LS2). Table 4.1 shows the chemical compositions of the lime used for the study while the mineralogical compositions of the two laterite samples are shown in Table 4.2.

Table 4.1: Composition of hydrated lime used for the study composition of hydrated lime used for the study

Constituents	Percentages (%)
Ca (OH)2	95.000
Chloride (Cl)	0.040
Sulfate (SO4)	0.400
Iron (Fe)	0.100
Heavy metals (as Pb)	0.005
Substances not precipitated by Ammonium oxalate (as Sulfate)	2.50
Loss on ignition	1.955

Table 4.2: Mineralogical Compositions of the raw laterite samples

Mineralogical Compositions	LS1	LS2
Quartz	Predominantly Present	Predominantly Present
Kaolinite	Predominantly Present	Moderately Present
Morganite	Sparingly Present	Moderately Present
Gismondine	Sparingly Present	Moderately Present
Sanidine	Sparingly Present	Sparingly Present
Muscovite	Sparingly Present	Moderately Present
Dickite	Sparingly Present	Sparingly Present

The XRD patterns for the two laterite samples are shown in Figure 4.1 (a) and 4.2 (b). From the XRD pattern of the laterite samples shown in Figure 4.1 (a) and 4.2 (b), quartz is the predominant mineral present in the two laterite samples. Quartz is a chemical compound made up of one-part silicon and two parts oxygen. It is silicon dioxide (SiO_2) having a Mohr's hardness of 7. It is highly resistant to both mechanical and chemical weathering resulting in its durability. This further depicts laterite as a promising material for construction because quartz is durable.

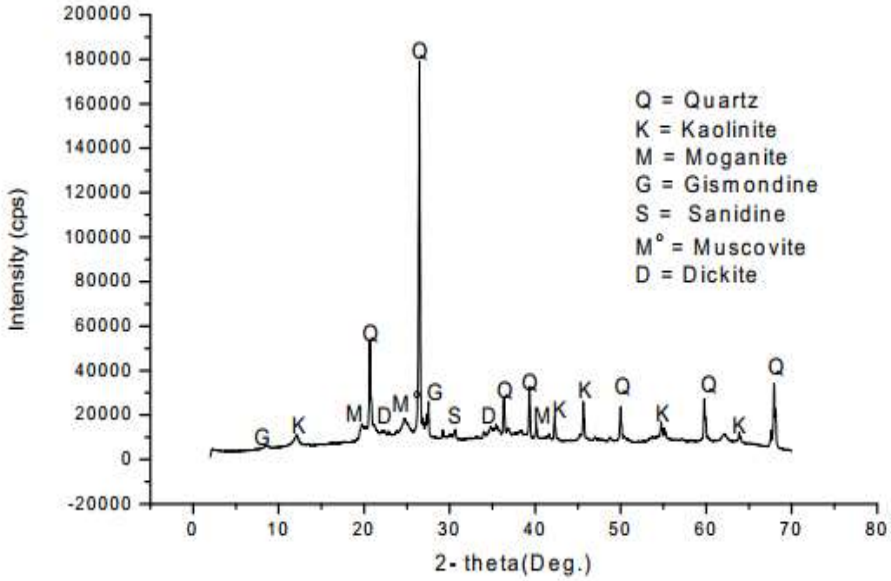

Figure 4.1(a): XRD pattern laterite sample I

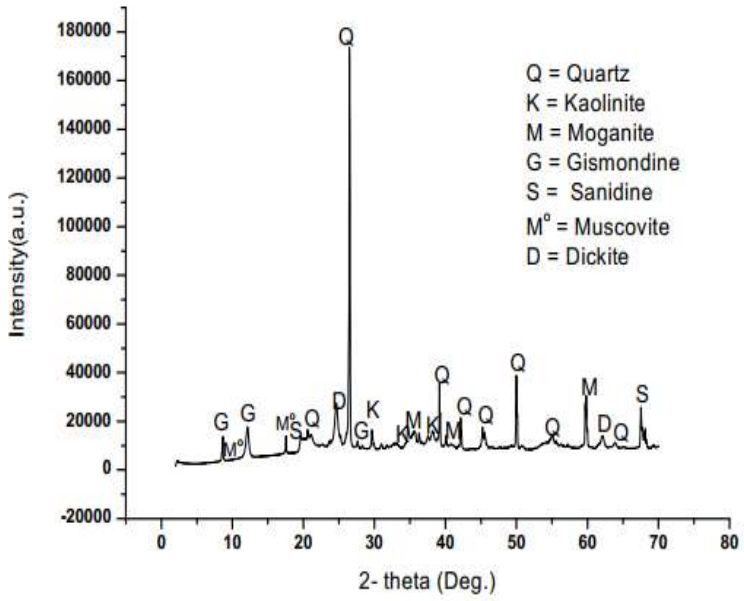

Figure 4.1(b): XRD pattern laterite sample II

4.2 Characterization of Bone Ash

The bone ash used for this research work was characterized using FTIR as shown in Figure 4.2. The FTIR identified the mineral as a poorly crystalline, CO_3^{2-} containing apatite, presenting bands typically described in hydroxyapatite. The ν3PO_4^{3-} (1200-900 cm–1) appeared as a broad band with a discrete shoulder. The ν1PO43– (980-940 cm–1) band was generally overlapped with the ν3 PO_4^{3-} whereas, the ν4PO_4^{3-} (650-500 cm–1) was partially resolved into two broad peaks. These shapes of the PO_4^{3-} – bands depict the low crystallinity of the minerals. The presence of CO_3^{2-}– was as a result of the clear bands of the ν3CO_3^{2-} (1600-1350 cm–1). Peaks of the ν1OH– (3572 cm–1) and ν2OH– (3572 cm–1) were observed to overlap each other as shown in **Figure 4.2**. A peak of νLOH– (630 cm–1) was not seen in the FTIR spectra. The presence of Isothiocyanate (2000 cm-1) was also observed

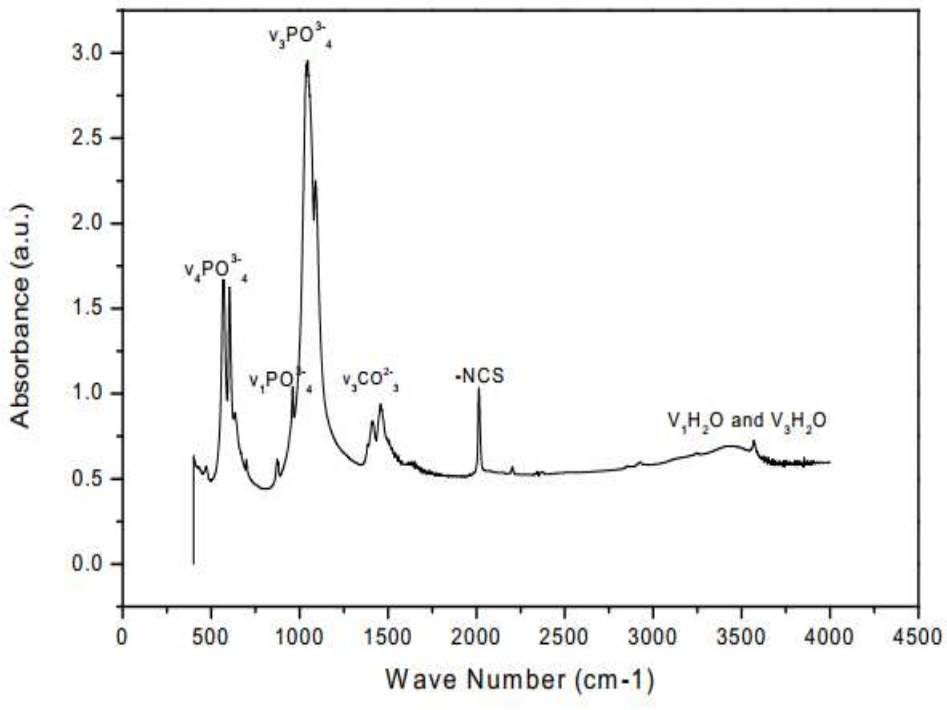

Figure 4.2: FTIR Spectra of Bone used for the Study

4.3 Sieve Analysis Results

The particle size distribution and classification for the two laterite samples used in this research were determined using British standards. Soils are generally as gravel, sand, silt or clay depending on the predominant size of particles present in the soil. Classification based on BS 1377: Part 2: 1990: 4.3 indicated that the particle size distribution curve observed in Figure 4.3(a) and 4.4(b) were that of silt.

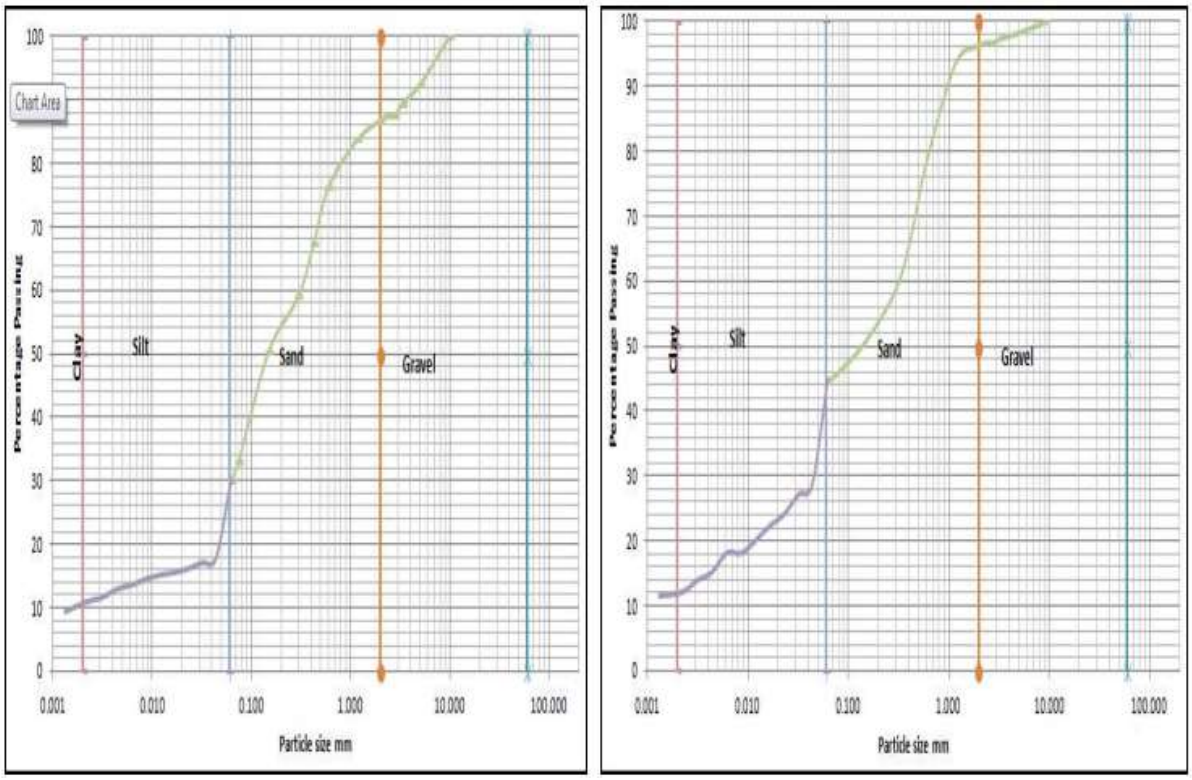

Figure 4.3(a): Particle size distribution of LSI Figure 4.3(b): Particle size distribution of LSI

4.4 Atterberg Limit Test Results

The Atterberg limits and classification for the two laterite samples used in this research were determined using British standards. Based on BS 1377: Part 2: 1990: 4.3 classification. Using the plasticity chart classification, the results obtained from the Atterberg Limits Test (Figure 4.4a and

4.4b) revealed that Laterite sample 1(LS1) was silt with high plasticity and hence had more clay content whereas Laterite sample 2(LS2) was silt with medium plasticity and hence had less clay content compared to LS1, as evidenced by their PI values. The natural moisture content determination showed that LS1 had higher natural moisture content compared to LS2, which had a lower moisture content. This implies that LS1 would definitely retain water more readily than LS2.

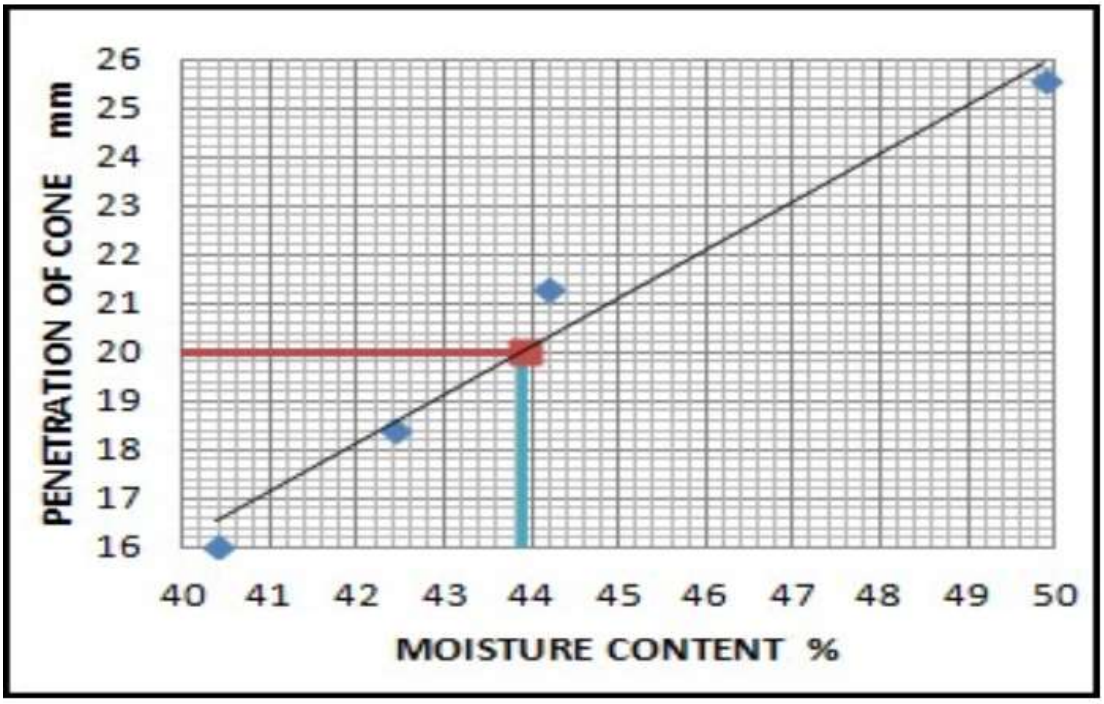

Figure 4.4(a): Atterberg Limits- Cone Test results for Laterite Sample 1

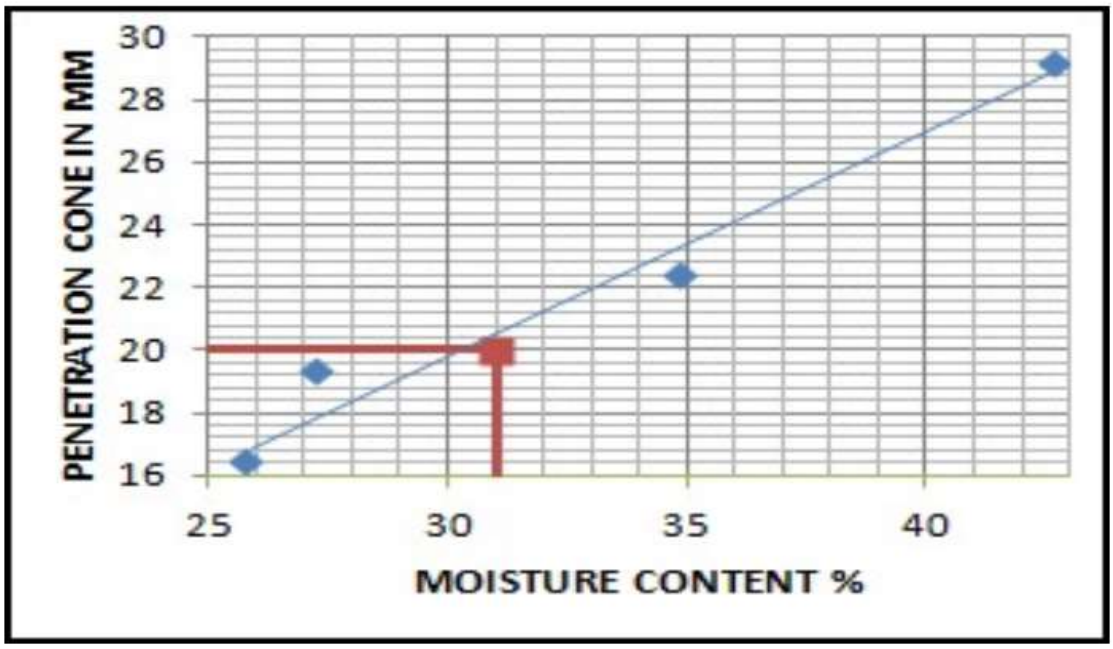

Figure 4.4(b): Atterberg Limits- Cone Test results for Laterite Sample 2

Table 4.3: Engineering Properties of Natural laterite samples used for this Research

Engineering properties of Laterite	LS1	LS2
Liquid limit, LL (%)	43.9	31
Plastic limit, PL (%)	24.39	21.41
Plasticity index, PI (%)	19.51	9.59
Plasticity Chart Classification	Silt with high plasticity	Silt with medium plasticity
Linear Shrinkage (%)	8.91	6.40
Moisture content (%)	24.39	21.41

4.5 Effect of Different Methods of Curing on Lime-Stabilized Laterite Samples

The effects of the different methods of curing on compressive strength of different compositions of tested samples were presented in the Figure 4.5. The samples cured using

air dried method of curing had the highest increase in their compressive strengths followed by those cured using the sun-dried method of curing, whereas those cured using the oven dried method of curing ha the lowest compressive strengths. The lower strengths observed for the samples cured using the oven dried method could be as a result of quick setting caused by the high temperature of the oven which resulted in visible cracks.

The higher compressive strength recorded for the sample cured using the air-dried method might be as a result of the presence of oxygen which controls the early hardening period and hence prevents quick setting of the stabilized bricks. It was also observed from Figure 4.5 that the compressive strengths of the samples cured using the air dried methods of curing increased optimally at 9% hydrated lime stabilization after which there was a decline in compressive strength

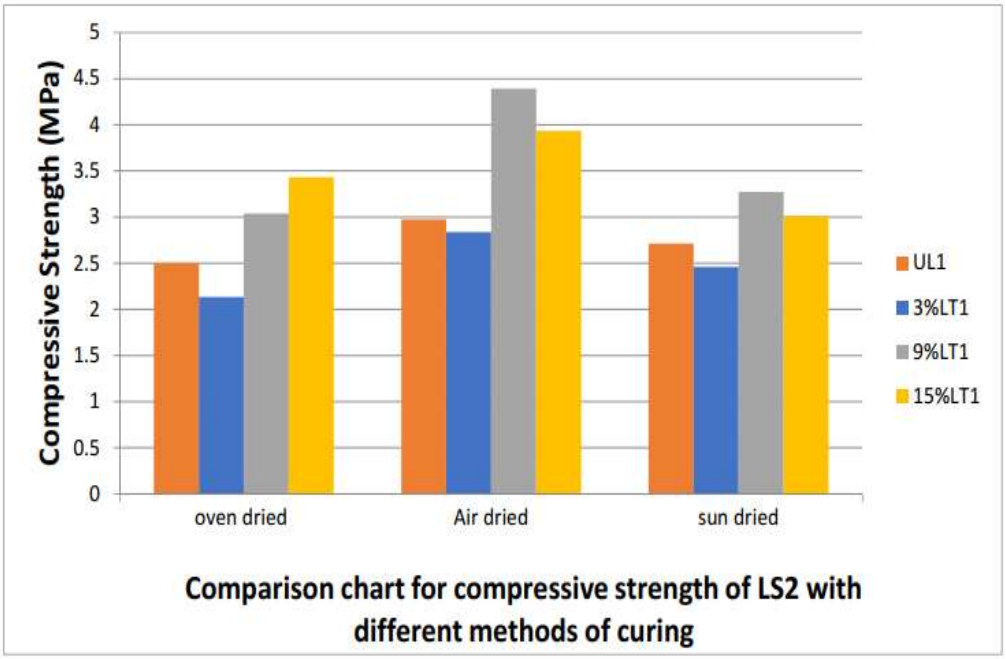

Figure 4.5 Effect of Different Methods of Curing on Lime-Stablized Laterite Sample

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Summary

The study was aimed at evaluation of clay laterite block in building construction in Keffi Local Govt Area of Nasarawa State. Three objectives which are to determine an appropriate mix proportion of stabilized laterite soil using hydrated lime and bone ash as stabilization agents, study the effect of hydrated lime and bone ash on the compressive strength of laterite and determine the effect of different methods of curing on the compressive strength of laterite.

In the chapter one background of the study, statement of the problem, purpose of the study, significance of the study, scope of work and research questions are discussed in detailed. The second chapter also discussed some concept of laterite block in building construction formation of laterite, occurrence of laterite, methods of soil stabilization, engineering classification of soil and review of empirical studies. Chapter three explain the step and process taken to construct and test of clay laterite block. The chapter four showed the structure and composition of samples, characterization of bone ash, 3 sieve analysis results, atterberg limit test results and effect of different methods of curing on lime-stabilized laterite samples. Finally the chapter five present summary of the studies, implication of the study, contribution to knowledge, conclusion, recommendations and suggestion for the further studies.

5.2 Implication of the Study

The following are implication of this study revealed the mineralogical compositions of the raw laterite samples by identification and characterization of laterite. The use of stabilization materials (lime and bone ash) to develop stabilized laterite and established of different methods of curing on both the stabilized laterite and untreated sample collected.

5.3 Contribution to knowledge

This study established the fact that samples improves optimally at 9% hydrated lime stabilization and 5% bone ash stabilization for samples cured using the air-dried method of curing for 28days. Then the poor durability and associated short service life of earth-based bricks affect the use of the material as a sustainable construction material.

5.4 Conclusion

The poor durability and associated short service life of earth-based bricks affect the use of the material as a sustainable construction material. Engineers recognize modification (stabilization) of engineering properties of soil as an important process of improving the performance of problematic soils and this makes marginal soils perform better as a civil engineering material. Based on the laboratory tests, lime and bone ash showed a good effect on stabilization treatment of laterite soil. In general, an additional amount of hydrated lime and bone ash caused the beneficial improvement in the compressive strength of laterite soil samples used in this research. It was observed from laboratory testing that the mechanical properties of stabilized soil vary and depend on the percentage of stabilizer used and also the curing method employed.

The result indicates that the compressive strength of the samples improves optimally at 9% hydrated lime stabilization and 5% bone ash stabilization for samples cured using the air-dried method of curing for 28days. It is concluded that the use of 9% by weight of the hydrated lime addictive and 5% by weight of bone ash addictive were the optimum amount for the stabilization of laterite soil. The outcome of this research indicates positive results due to the potential of hydrated lime and bone ash to strengthen the laterite. It also shows that bone ash is a sustainable alternative for hydrated lime in stabilization of laterite material. The property of laterite can be

enhanced by suitable water proofing treatments and studies on how to achieve this are to be carried out in future research.

5.5 Recommendations

Based on the conclusion of the study, the following recommendations were made:

1. This research recommends the use of local materials like laterite in developing countries due to its cost effectiveness and energy efficiency than that of conventional modern materials.
2. T ϖ A classification system for laterite based on its applications for different functions for better management and utilization of the material.
3. ϖ Definition of guidelines and standardized procedures for selection of laterite for building applications. This will help to curb numerous conflicting viewpoints brought out by various research studies.
4. ϖ Scientific understanding of laterite as a construction material is highly relevant for its sustainable utilization worldwide. ϖ Long-term study to find an optimum size for its varied masonry applications.
5. ϖ Good policies, especially by encouraging research on local materials and by implementing effective training programs on the use of earth-based constructions.

5.6 Suggestion for Further Studies

1. Further studies on structural evaluation and statistical analysis to arrive at more conclusive suggestions for laterite standards.

REFERENCES

AB Aziz, N.N.S. N, and Mukri, M. (2016)**.** The Effect of Geopolymer on the Compaction Parameter of Laterite Soil. *Middle-East J. Sci. Res.*, 24 (5), 1588-1593.

Achampong, F., Anum, R.A., Boadu, F., Djangmah, N.B., Chegbele, L.P. (2013). Chemical Stabilization of Laterite Soils for Road construction: Case Study: The Laterite Soils at Legon, International Journal of Scientific & Engineering Research, Volume 4, Issue 11, November-2013

American Association of State Highway and Transportation Officials (2005), Freezing and Thawing test of Compacted Soil-Cement Mixtures, AASHTO designation T 136-97.

ASTM D 2216 - Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures.

ASTM D 4318 - Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

ASTM, Standards on Soil Stabilization with Admixtures. 2nd edition. 126. Retrieved 2014-03-23.

Ayininuola G.M. and Akinniyi B.D. (2016). Bone Ash Influence on Soil Consolidation. Malaysian Journal of Civil Engineering 28(3): 407-422

Ayininuola, G.M, and Sogunro, A.O. (2013) *Bone ash Impact on Soil Shear Strength*. International Journal of Environmental, Earth Science, and Engineering, World Academy of Science and Technology 7, (11): 330–334.

Azeko, S. T. (2015) Biodegradation and Recycling of Polyethylene into Composite Building Materials. Dissertation.Doctor of Philosophy (Materials Science and Engineering) African University of Science and Technology: Abuja, Nigeria

Das, B.M. (2003). Chemical and Mechanical Stabilization. Transportation Research Board.A2J02: Committee on Chemical and Mechanical Stabilization.

Gidigasu, M.D. (1976), laterite, soil engineering, *development in geotechnical engineering*, vol.9, 420-477 pp.

Kasthurba, A K, Reddy, K. R. And Reddy, D. V. (August 2014) Use of Laterite as a Sustainable Building Material in Developing Countries. International Journal of Earth Sciences and Engineering.ISSN 0974-5904, Vol. 07, No. 04, Pp. 1251-1258

Kerali, G. (2001). *Durability of Compressed and Cement-Stabilized Building Blocks*; Ph.D. Thesis; School of Engineering, University of Warwick: Warwick, UK.

Kogbe, C.A.(Editor), 1975. Geology of Nigeria. The Elizabethan Publishing Co., Lagos, pp 332–338

Lemougna, P.N., Melo, U.F.C, Kamseu, E. And Tchamba (2011). Review: Laterite Based Stabilized Products for Sustainable Building Applications in Tropical Countries: Review and Prospects for the Case of Cameroon. Sustainability, 3, 293-305.

Loveridge, N. (1999). Bone: more than a stick. J. Anim. Sci. 77(2), 190–196.

Marto, A., Latifi, N., Sohaei, H. (2013). Stabilization of Laterite Soil Using GKS Soil Stabilizer. *EJGE*. 18: 521–532

Mustapha, K., Annan, E., Azeko, S. T., Kana, M. G. Zebaze and Soboyejo, W. O. (2015). Strength and fracture toughness of earth-based natural fiber-reinforced composites. *Journal of Composite Materials*,0021998315589769.

Mohd Yunus, N.Z., Chin Yung, Y., Ng Teck Wei, Abdullah, N., Mashros, N. and Abdul Kadir, M.A., (2015) Jurnal Teknologi (Sciences & Engineering). 72:3 pp 91–97

Nanda, R.L. and Krishnamachari, R.,(1958). Study of soft aggregates from different parts of India with a view to their use in road construction, II. Laterite. *Central Road Res. Inst.,Inbia*, 32 pp

Norton (2000). Understanding Pottery Techniques. New York Studio Vista Publisher, pp 102-115

Onyelowe K.C. (2016) Kaolin Stabilization of Olokoro Lateritic Soil Using Bone Ash as Admixture International Journal of Constructive Research in Civil Engineering (IJCRCE) Volume 2, Issue 1, PP 1-9 (Online) www.arcjournals.org

Persons, B.S. (1970) Laterite; genesis, location, and use (In) *RW Fairbridge Monographs in Geoscience*, Plenum Press, New York.

Sergio M. (2008). Available technologies for local building materials. United Nations Industrial Development Organization and the International Centre for Science and High Technology, p. 2.

Thagesen, B. (1996), Tropical rocks and soils, in: Highway and traffic engineering in developing countries: B, Thagesen, ed. Chapman and Hall, Londons.

Whittington, B.I.and Muir, D. (2000). 'Pressure Acid Leaching of Nickel Laterites': A Review. Mineral Processing and Extractive Metallurgy Review. 21(6): 527-599.